UNE 1960
OLUME 3 • NUMBER 6

- Norris & Byck — Analog Simulation: A Network Method For Solving Microwave Problems.
- Cappucci — Zero-Loss Wideband Coaxial Line Variable Attenuators.
- Barrington — Microwave Engineering Aspects of Electron Linear Accelerators — Part II.

he microwave journal

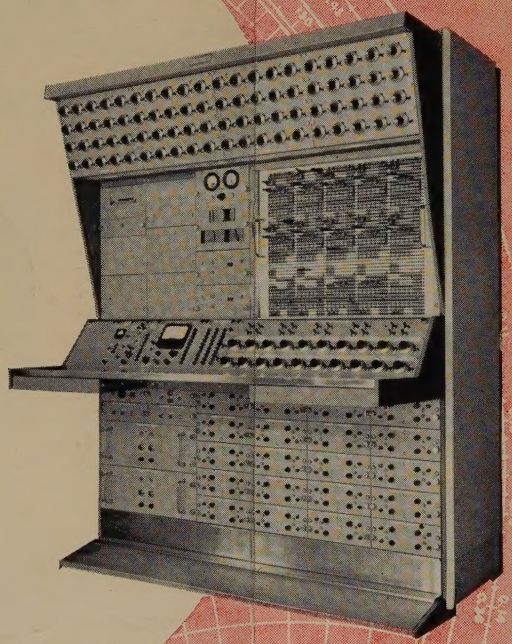
$$V_n = Z_n \sum_{1}^{n-1} kV_m \sin \theta_{nm}$$

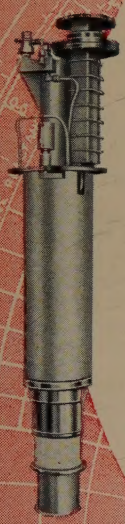
Equation represents a mathematical model of a multi-cavity Klystron. This dictates computer patchboard wiring resulting in the electrical simulation of the mathematical model.

1.

2.

Control settings on the computer representing cavity tunings, dimensions and beam characteristics are adjusted while observing the response on the plotter.



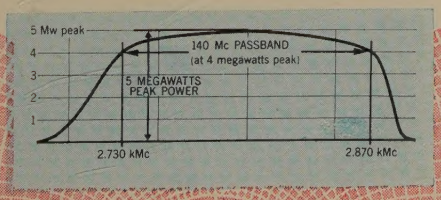


4.

The computer process was used in the broad-banding of this Klystron.

3.

Adjustments are continued on the computer until desired bandwidth characteristics are obtained.



DR BERNARD HARRIS
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Also In This Issue . . .

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Interested in swept frequency testing? Ask your rep, or write direct for "Applications of hp 416A Ratio Meter," describing reflectometer systems and hp swept frequency measuring techniques.

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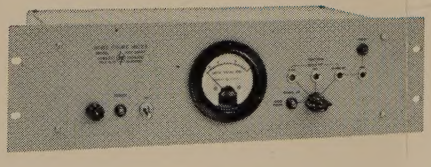


hp 344A Noise Figure Meter

Quickly, accurately measures noise figure of operating radar sets. Automatic operation; simple front panel calibration. Militarized, transistorized, reliable in extreme environments, minimum size and weight. Continuous noise figure presentation on most radar receivers. Extremely high sensitivity permits decoupling noise source up to 20 db from main transmitter line to minimize system degradation. Provision for automatic alarm, remote noise figure monitoring, modulating. Meter scale/excess noise options; 30 MC input frequency, 1 MC bandwidth, 75 ohms input impedance. Approx. $1,600.00 (depending on options and modifications selected).

hp 340B/342A Noise Figure Meters

General-purpose instruments making possible, in minutes, receiver and component alignment jobs that once took hours. Simplifies accurate alignment; encourages better maintenance; better performance.

hp 340B automatically measures, continuously displays IF or rf amplifier noise figure at 30 or 60 MC; other freq. on order. $715.00 (cabinet) $700.00 (rack).

hp 342A, similar, operates on 30, 60, 70, 105, 200 MC. 30 MC and 4 other frequencies between 38 and 200 MC on order. $815.00 (cabinet) $800.00 (rack). (Note: Models 340B and 342A available only in the U.S.A. and Canada)

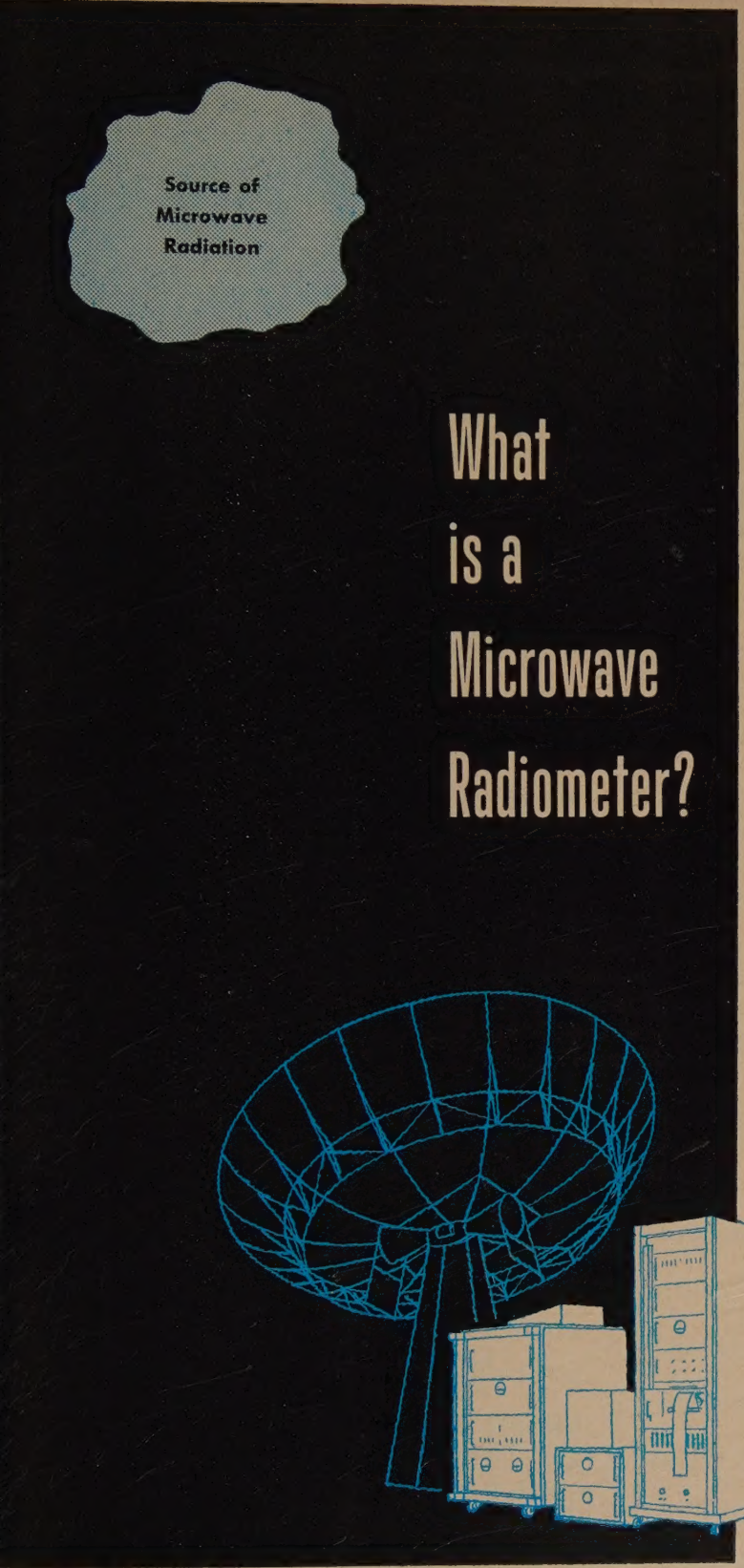
hp 343A vhf Noise Source, temperature limited diode broadband source, 10 to 600 MC, 5.2 db excess noise, $100.00.

hp 345B IF Noise Source, 30 or 60 MC (others to order); 4 impedances, 5.2 db excess noise. $75.00.

hp 347A Waveguide Noise Source, Argon gas discharge tubes in waveguide section; for bands S, G, J, H, X, K, 2.6 to 18.0 KMC, 15.2 db excess noise. $190.00 to $250.00.

Basic test, power and impedance measuring equipment

Circle Reader Service Card 66



What is a Microwave Radiometer?

The fundamental ingredients of any microwave radiometer consist of an antenna, an amplifier, a detector, and an indicator. From a thermodynamic standpoint the antenna may be considered as a device which transports its radiation resistance at the input terminals of the receiver into a thermal reservoir contained within the volume of space "observed" by the antenna and determined by its directive characteristics. If we then assume that the observed medium is a composite black body reservoir at some temperature T, then the temperature of the radiation resistance of the antenna will come into equilibrium with the temperature of this reservoir. The amplifier portion of the receiver then amplifies the power presented to its input terminals by the radiation resistance. This power level is the well known Johnson noise power KTB where K is Boltzmann's constant, T is the equivalent temperature of the radiation resistance and B the predetection bandwidth of the amplifying device. The power input to the amplifier is then equivalent to the power output of a resistor matched to the receiver input, and immersed in a thermal reservoir at temperature T. Since this power level is directly proportional to the temperature of the reservoir, the signal input can be expressed in temperature units (of degrees Kelvin).

In the Rayleigh-Jeans approximation for the brightness of Planck radiation, the brightness per unit cycle is inversely proportional to the square of the wavelength, whereas Johnson noise power is independent of frequency and dependent only upon temperature. The thermodynamic balance of the two sources of power is obtained, in a receiving system, through the wavelength characteristic of the average antenna cross section. When performing the integration of the product of brightness per unit wavelength and antenna cross section, over the bandwidth of the receiver and the solid angle of the antenna aperture, the wavelength-dependent terms cancel. Hence an antenna totally "immersed" in a black body at temperature T will contribute a constant power output at its terminals, independent of frequency.

In summary, the logic is as follows: The power incident upon the antenna aperture within the bandwidth of the receiving system produces a thermal bath for the radiation resistance of the antenna, at the temperature of the "composite equivalent" black body viewed by the antenna. This antenna temperature is then transmitted to the amplifier via the "Johnson noise mechanism," where it is amplified in the presence of the noise power attributable to the man-made circuitry.

The signal strength is recorded in temperature units (degrees Kelvin).

Ewen Knight radiometers of the HII series are capable of detecting temperature changes at the receiver input terminals as low as 0.01°K, which is approximately 10^{-25} watts/cps.

Ewen Knight CORPORATION
AT THE FRONTIERS OF Electronics
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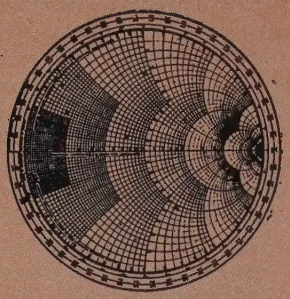

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• Widest range!

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MODEL 440 ... **$250**

What's most important to you in a power meter? Accu-y? Portability? Independence from line voltage deviations? de range? Stability? Rapid warm-up?

Not that you have to make a choice...or a compromise any longer. The Narda Model 440 Power Meter gives you these features! Completely transistorized and powered by nickel-cadmium battery, rechargeable during operation or ernight, it offers two low-power scales in addition to the e standard scales (see below), a built-in charger with state-of-charge indicator and protection against overcharging, and freedom from internal heating caused by vacuum tubes.

Moreover, the 440 provides up to 18 ma bias current, enabling you to use the widest selection of bolometers and thermistors. In short, the 440 is the most versatile unit available to provide accurate direct-reading measurements of cw or pulsed-power automatically, over any frequency range for which there are bolometer or thermistor mounts. For complete data, contact your nearest Narda representative, or write us directly. Address: Dept. MJ-11.

SPECIFICATIONS

POWER RANGES: 7 SCALES

01 mw full scale	—30 to —20dbm
03 mw full scale	—25 to —15dbm
1 mw full scale	—20 to —10dbm
3 mw full scale	—15 to —5dbm
0 mw full scale	—10 to 0dbm
0 mw full scale	—5 to +5dbm
) mw full scale	0 to +10dbm

ma bolometers give best results on these scales.

Range Switch: 0.01 to 10 mw (full scale)

Accuracy: 3% of full scale reading

Bolometers & Thermistors: All 100 and 200 ohm, requiring up to 18 ma bias.

Battery Charger: Built-in; continuous or overnight. (Battery operable 16 hrs. before recharge required.)

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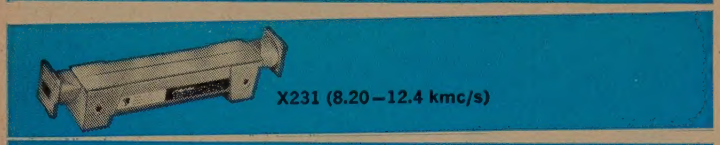
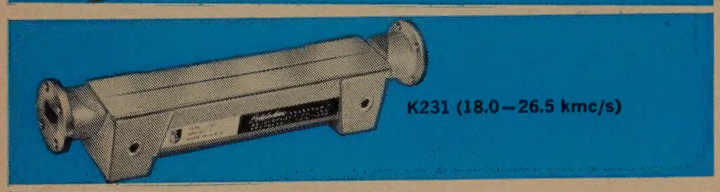
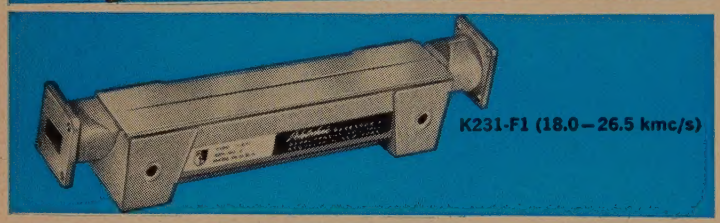
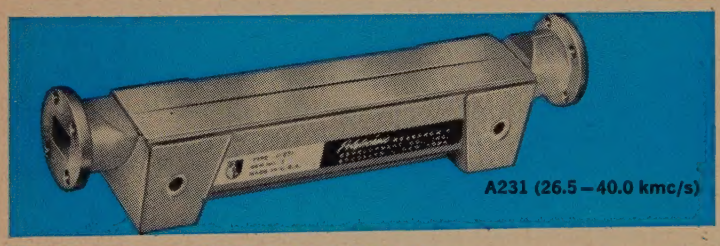
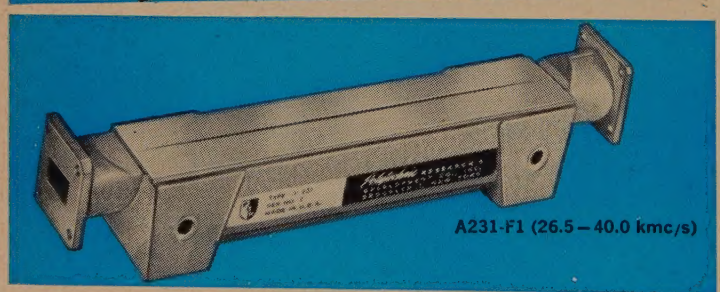
ONE FOR ALL and ALL NEW

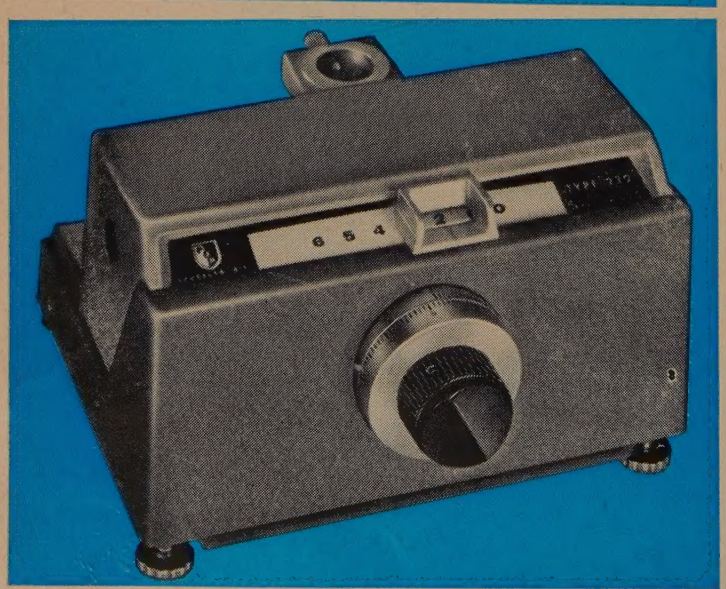












Completely covers the frequency range from 4.0 to 40.0 KMC/S with only one probe carriage.

The new PRD 230 Universal Probe Carriage represents a major achievement in accurate standing wave and impedance measurements. Here is a precision instrument which features bold, rugged styling with laboratory accuracy. The position of the probe holder can be quickly determined to 0.01 mm.

A complete series of Waveguide and Coaxial Slotted Lines are available for snap-in convenience and low VSWR performance. Unusual features include a scale calibrated directly in dial revolutions and self-contained slope adjustment of the U, K, and A band Slotted Lines.

PROBE CARRIAGE: Accepts both PRD 250-A Broadband probe for 4.0 to 12.4 KMC/S and PRD 253 Fixed Tuned Probe for 12.4 to 40 KMC/S.

VSWR: PRD 231 Waveguide Slotted Lines have a maximum residual VSWR of 1.01.

VERNIER RESOLUTION: 0.01 mm.

PROBE TRAVEL: 6 cm.

PRD 231* SERIES SLOTTED LINES

PRD Type	Frequency Range (kmc/s)	Transmission Line Size (Inches)	Length (Inches)	Couplin Type
N231	4.0-10.0	3/8" Coaxial	9-1/4	**
X231	8.20-12.4	1 x 1/2	9	UG-39/U
U231	12.4-18.0	.702 x .391	9	UG-419/
K231	18.0-26.5	.500 x .250	9	UG-425/
K231-F1	18.0-26.5	.500 x .250	9	UG-595/
A231	26.5-40.0	.360 x .220	9	UG-381/
A231-F1	26.5-40.0	.360 x .220	9	UG-599/

*Available in WR waveguide sizes on special order.
**Normally supplied with Type "N" male and female adapters (PRD 367 and 368).
Adapter for Type "C" male and female (PRD 3354 and 3355).
Adapter for "TNC" male and female (PRD 3395 and 3396).

PRD ELECTRONICS, INC.
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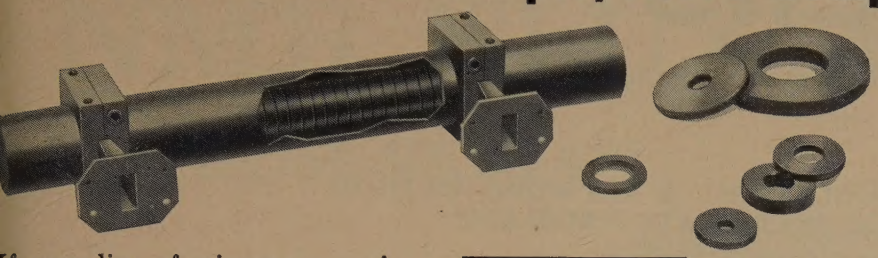
INDOX I and INDOX VI Permanent Magnets

Make Possible Simple, More Compact TWT Design



If your line of microwave equipment includes traveling wave tubes, you will be interested in Indiana Steel's amazing ceramic permanent magnets called INDOX.

Unlike heavy Alnico materials, INDOX offers designers of microwave equipment a new, light, inexpensive and easy-to-assemble permanent magnet in the sizes, shapes and strengths necessary for today's critical applications.

For example, in periodic focusing traveling wave tubes, INDOX can supply a much higher flux density due to its higher intrinsic coercive force. And INDOX pieces may also be magnetized prior to assembly without appreciable loss of flux density.

Not only does INDOX open new doors of design, but Indiana Steel now offers two grades of INDOX to meet special microwave design problems—INDOX I and INDOX VI.

INDOX I

In addition to having a higher intrinsic coercive force than Alnico, INDOX I is an inexpensive material manufactured to design specifications at moderate die cost. Irreversible flux density losses do not occur until very low operating temperatures are reached. And INDOX I produces a greater flux density than many other materials when operating low on the demagnetization curve. (See curve below.)

INDOX VI

Through extensive research in Indiana's R&D laboratories, a new, more powerful INDOX material has now been released for use in microwave equipment, particularly the TWT's. Having a greater energy product, INDOX VI can be used when a greater flux density is required or when a smaller magnet must be used.

AVAILABLE FROM STOCK NOW!

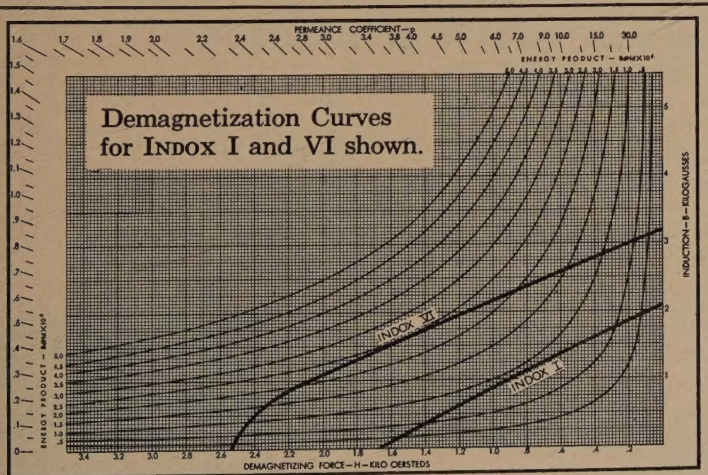
Many unground sizes of INDOX I and VI magnets are now in stock. If required, magnets may be ground to closer tolerance prior to assembly. Magnets may be magnetized before or after shipment, as desired.

DESIGN ENGINEERING NOTE:

Indiana manufactures the widest selection of permanent magnet materials, available in thousands of sizes and shapes. Therefore, you can depend upon Indiana to give unbiased advice in choosing the correct magnet material for your application.

What are your permanent magnet requirements in the broad-band microwave field? It's likely an experienced Indiana application engineer can help you, so write for full information. Request Bulletin 18Q2 (INDOX I and V) and Bulletin 353Q3 (INDOX VI).

NEW! *Recently published data on predicting effect of low temperature on* INDOX V *and* VI, *compiled by Indiana scientists. For your copy, write for Applied Magnetics, Fourth Quarter, 1959.*



TYPICAL CHARACTERISTICS

	INDOX I	INDOX VI
Coercive Force (H_c) oersteds	1,825	2,550
Residual Induction (B_r) gauss	2,200	3,200
Peak Energy Product (B_dH_d)	1.0×10^6	2.4×10^6
Reversible Permeability	1.2	1.06
Temperature Coefficient	—0.19%/°C	—0.19%/°C
Magnetization Field for Saturation, oersteds	10,000	10,000
Chemical Composition	$BaFe_{12}O_{19}$	$BaFe_{12}O_{19}$
Specific Gravity	4.7 or 0.17 lb/cu in	4.5 or 0.162 lb/cu in

INDIANA STEEL PRODUCTS

Division of Indiana General Corporation

Valparaiso, Indiana

In Canada: The Indiana Steel Products Company of Canada Limited, Kitchener, Ontario

INDIANA PERMANENT MAGNETS

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MICROVIEWS OF THE MONTH

43 ▶ **ANALOG SIMULATION: A NETWORK METHOD FOR SOLVING MICROWAVE PROBLEMS**

Allen Norris and Donald M. Byck

The application of analog computers to microwave problems is described in this paper. The problems selected for treatment are among those which frequently occur in microwave engineering analysis: electron focusing or trajectory analysis, frequency spectra, amplifier broadbanding, waveguide propagation characteristics and microwave cavity resonance analysis. These problems were chosen to illustrate the analog computer techniques which are applicable to different types of mathematical models. The problem models are, respectively, ordinary differential equations, definite integrals, algebraic equations and partial differential equations.

49 ▶ **"ZERO"-LOSS WIDEBAND COAXIAL LINE VARIABLE ATTENUATORS**

Joseph D. Cappucci

The use of strip transmission line (or rectangular cross-section coaxial lines) has been much discussed in literature. There are, however, many interesting variations of this line which can be utilized to build devices with exceptional performance. One of these cross-sections is the ridge coaxial line described in this paper. The use of this ridge coaxial line allows for the construction of a "zero" insertion loss attenuator having positive, negative or flat attenuation characteristics over a full octave.

54 ▶ **MICROWAVE ENGINEERING ASPECTS OF ELECTRON LINEAR ACCELERATORS — PART II**

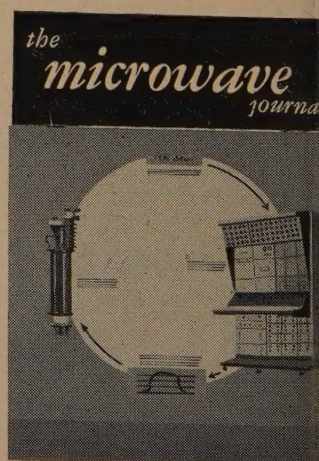
Alfred E. Barrington

Part I of this survey appeared in the April, 1960, issue and discussed theoretical aspects of accelerating waveguide structures. In Part II, presented here, Dr. Barrington deals with engineering and operational aspects of these important research tools.

OUR COVER

This month's cover represents the simulation of a multi-cavity klystron for broadbanding design. The tube is Varian Associates' VA-839, seven-cavity klystron. The computer is an Electronic Associates PACE 231-R analog computer. The work described was performed at the Electronic Associates Computation Center at Los Angeles.

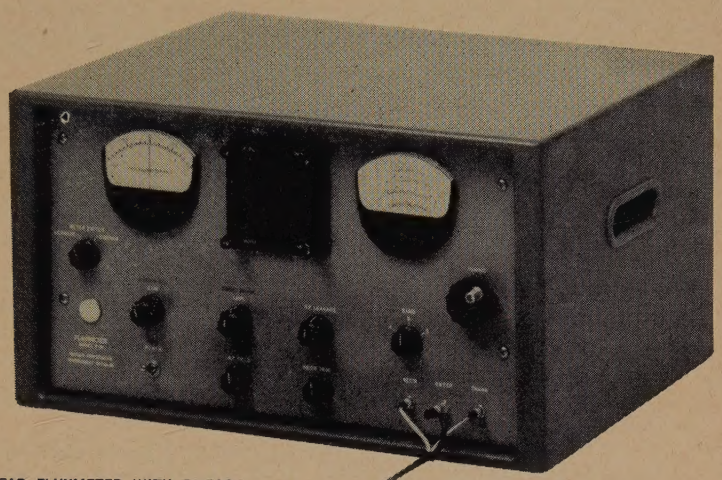
See page 43.



NEW NMR FLUXMETER

(Nuclear Magnetic Resonance)

FROM VARIAN



VARIAN MODEL F-8 NUCLEAR FLUXMETER WITH 50-FOOT EXTENSION CABLE REPRESENTED BETWEEN MAIN UNIT AND FIELD PROBE. 6-FOOT EXTENSION CABLE IS STANDARD EQUIPMENT.

The Varian Model F-8 Nuclear Fluxmeter provides precise *measurement* and/or *control* of magnets used in laboratory and industrial applications.

As a control device, the F-8 Fluxmeter holds fields stable against residual slow drift or external stray magnetic interferences not sensed by straight current regulation. Furthermore, the F-8 is capable of providing such control at extended distances from the magnet by mere addition of an accessory cable.

The frequency-determining (hence field-determining) circuitry of the F-8 Fluxmeter is buffered completely from the crossed-coil probe by several stages of amplification. Thus, for example, the varying probe position encountered during field plotting cannot inadvertently reduce accuracy.

CHARACTERISTICS AND ADDITIONAL FEATURES

- Wide frequency range and two probe samples (H^1 and H^2) permit field coverage from 1,000 gauss to an upper limit of 52,000 gauss.
- Accuracy—a function of signal-to-noise ratio, inherent sample line-width, and inhomogeneity of the field being measured — is as follows:

  ±0.05 gauss with 1 gauss external field gradient across ¼" diameter proton sample of 0.5 gauss natural line-width, using external frequency counter.

  ±0.2% with vernier and calibration curve (furnished).
  ±5% on convenient, direct-reading dial.

  Absolute accuracy is also limited by the accuracy of the NBS accepted determination for the gyromagnetic ratio of protons in water (approximately 1 part in 10^6).
- Standard probe cable is 6 feet long.
- F-8 may be used for NMR class-room experiments and demonstrations; absorption or dispersion signal may be chosen at will by one-knob balance adjustment on main unit.
- Plug-in jacks at rear of chassis permit external frequency measurement and crystal lock-in of transmitter.
- Control output suitable for direct use with Varian Regulated Magnet Power Supplies.
- Samples can be supplied in a choice of natural line widths for best match to available field homogeneity.
- Sweep amplitude and transmitter power are adjustable for optimum performance.

For full specifications, write the **Instrument Division,**

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PALO ALTO 34, CALIFORNIA

NMR & EPR SPECTROMETERS, MAGNETS, FLUXMETERS, GRAPHIC RECORDERS, MAGNETOMETERS, MICROWAVE TUBES, MICROWAVE SYSTEM COMPONENTS, HIGH VACUUM EQUIPMENT, LINEAR ACCELERATORS, RESEARCH AND DEVELOPMENT SERVICES

Circle Reader Service Card 5

SECURITY?

With the increased complexity of our society, we are seeing a gradual trend towards true socialism — not only here in our own country, but all over the world. There seems to be a prevalent desire on the part of individuals for security — birth to grave security — and a corresponding willingness on the part of government, business, and unions to satisfy and encourage the desire.

Many countries are moving in that direction either deliberately or inadvertently, our own included. In our own country the process is being accelerated by big business and big labor. They are both working to provide the working individual with the aforementioned security.

Although labor unions are beginning to make inroads into the engineering community, it is company sponsored security that most concerns the engineer. Today an engineer can participate in pension plans, insurance plans, profit sharing plans, stock plans, etc., all offered by the company of his choice.

Many of the plans are so designed that an individual can benefit only if he remains with a given organization for an extended period of time. In some cases the minimum time is measured to the retirement age.

In addition to the financial plans, a company is assisted in holding an engineer by the unwritten laws of seniority.

Personally, we have no criticism with any of the company security inducements. Our own personal belief is that they serve a purpose and provide a man something to look forward to, more than just working to extinction.

What we do object to is the tendency on the part of a growing number of people to work only for the long term security offered by these companies. The fact of the matter is that true security is found only within the individual himself, and not in any program, ladder of promotion, or years of participation.

Security is something that concerns itself with the ability to do the best with the tools at hand. The best security for an engineer is an open mind, the willingness and ability to work, and the willingness and ability to contribute.

The good points of long term security provided by an ever increasing number of companies have been discussed and applauded at great length. We only wish to put it in its proper perspective.

The individuals who live only for the fruits of company security are in danger of becoming human vegetables with neither character nor independent thought.

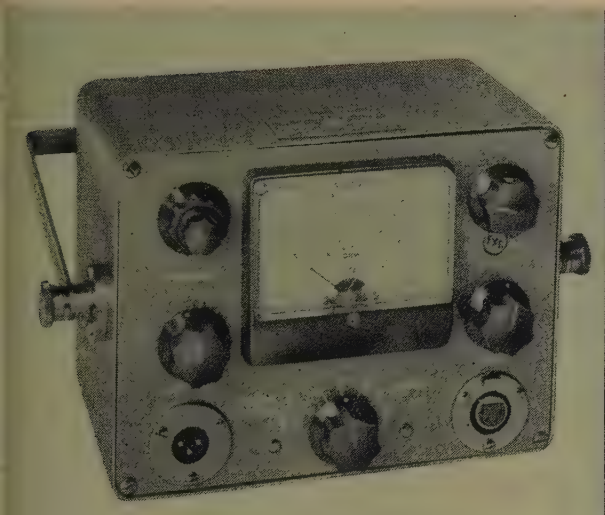
Many individuals in our society are gradually easing into the comfortable atmosphere of "the world owes me a living." This is an unhealthy situation. If too many of us persist in this attitude, someone else will come along and work harder than we do and will pick up all the marbles.

Ted Saad

FXR TRANSISTORIZED
TEMPERATURE COMPENSATED
POWER METER

Measures RF and Microwave Power with Incredible Stability!

When used in conjunction with an FXR Series 218* Temperature Compensated Thermistor Head, the *Power Meter* is a hundred times more stable than comparable instruments, due to a unique method of compensating for ambient temperature changes.



Model B832T, Price $450.00

- Readings are virtually drift-free.
- Five direct reading ranges—30 microwatts to 3 milliwatts full scale.
- DC calibration at all levels.
- Range switching without recalibration.
- Self-contained re-chargeable nickel cadmium battery—use to charge ratio, 2 to 1.

* Available in coaxial and waveguide sizes from 0.01 to 40.00 KMC.

Complete details for the asking.

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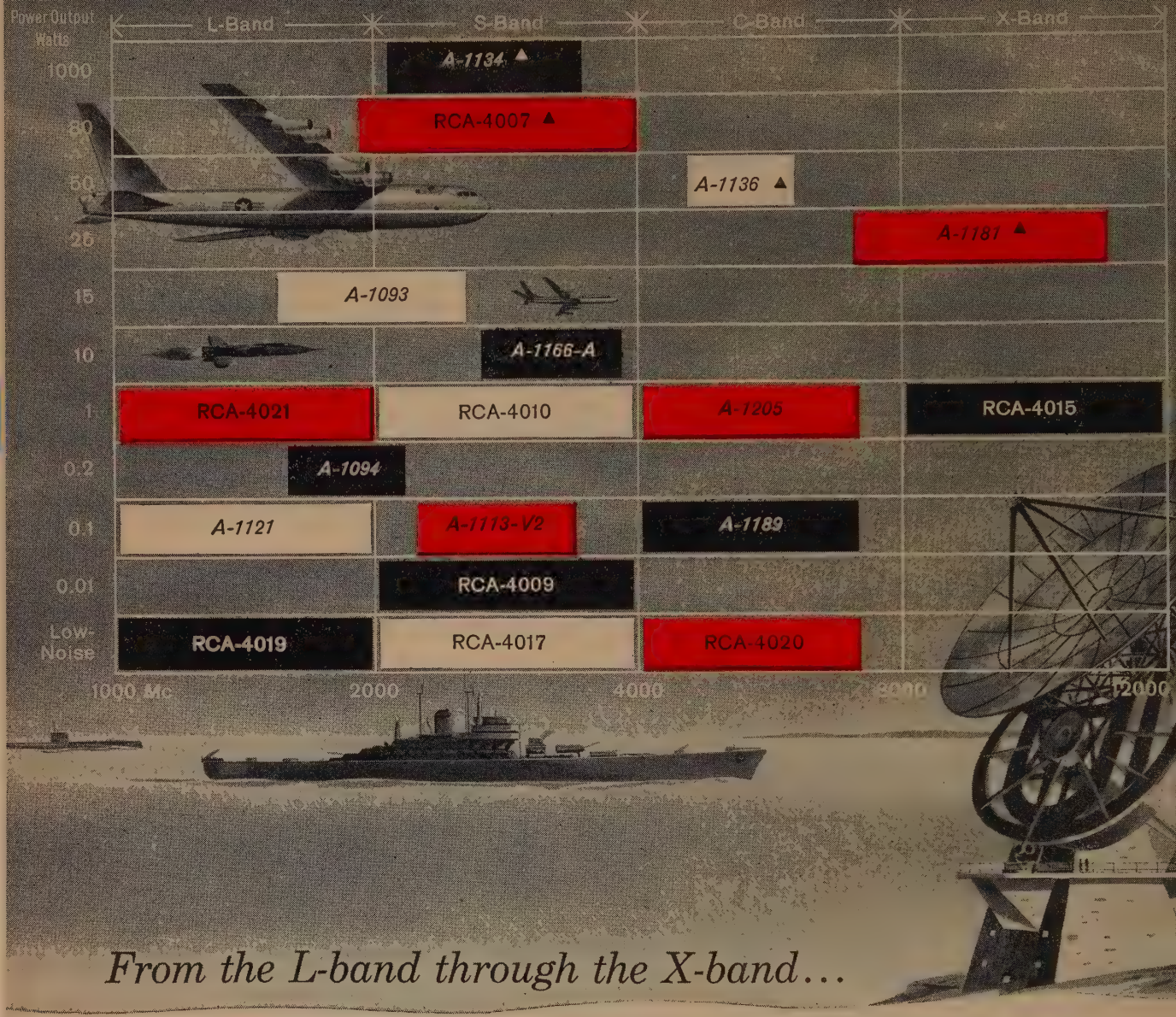
Woodside 77, N. Y. TWX: NY 43745

ecision Microwave Equipment • High-Power Pulse Modulators • High-Voltage Power Supplies • Electronic Test Equipment

Circle Reader Service Card 6



From the L-band through the X-band...

There's a reliable RCA Traveling-Wave Tube for your needs

The chart above shows the wide range of RCA traveling-wave tubes available for your designs. New types and improved versions are constantly being added to the list. Each of them is designed for long life and reliable performance. In fact, *RCA gives you a 1,000-hour warranty on all commercial TWT types.*

Under actual field conditions, it is often possible to obtain unusually long and reliable operation from RCA TWTs. For example, a recent letter from Jacques Baerlocher Corporation in Zurich reported: "The RCA-6861 installed in the equipment at Zurich Airport just failed 19,200 hours of service. It is interesting that the tube kept its good properties until hours." Performance records such as this result of advanced design plus the painstaki RCA puts into the manufacture of TWTs.

For complete information on RCA Travelin Tubes and how you can obtain "customized to meet your specific requirements, get in with the RCA Field Office nearest you.

RADIO CORPORATION OF AMERICA *Electron Tube Division* *Harri*

ANOTHER RCA CONTRIBUTION TO MICROWAVE ELEC

Government Sales: Newark 2, N. J., 415 S. 5th Street, HUmboldt 5-3900; Dayton 2, Ohio, 224 N. Wilkinson St., BAldwin 6-2366; Washington 6, D.C., 1625 "K" St., N.W., DI
Industrial Tube Products Sales: Newark 2, N. J., 744 Broad St., HUmboldt 5-3900; Detroit 2, Michigan, 714 New Center Building, TRinity 5-5600; Chicago 54, Illinois, Merchandise Mart Plaza, WHitehall 4-2900; Los Angeles 22, Calif., 6355 E. Washington Blvd., RAymond 3-8361

MICHAELS ELECTED PRESIDENT OF PRD ELECTRONICS

Henry H. Michaels, Jr. has been elect- president of PRD Electronics, Inc., ooklyn, N.Y.

Michaels was formerly executive vice esident of Aircraft Radio Corp. Prior that he was senior vice president of action Motors, Inc., where he served years.

George S. Dively, chairman and pres- nt of Harris-Intertype, said, "This is important step in our program to velop PRD's full growth potential as e of the pioneering firms of the mi- wave industry."

Michaels will succeed Dr. Ernst eber, who has been serving as interim esident of PRD Electronics, formerly own as Polytechnic Research and De- opment Company. Dr. Weber, pres- nt of the Polytechnic Institute of ooklyn and an internationally recog- ed authority on microwave electron- will continue with PRD as a technical l management consultant.

Dively said that Harris-Intertype plans continue increasing its electronic siness. He noted, "we feel Michaels' ofessional management experience in owing scientific companies will be a l asset in the future development of D Electronics."

He is a graduate of Lafayette College.

—m w j—

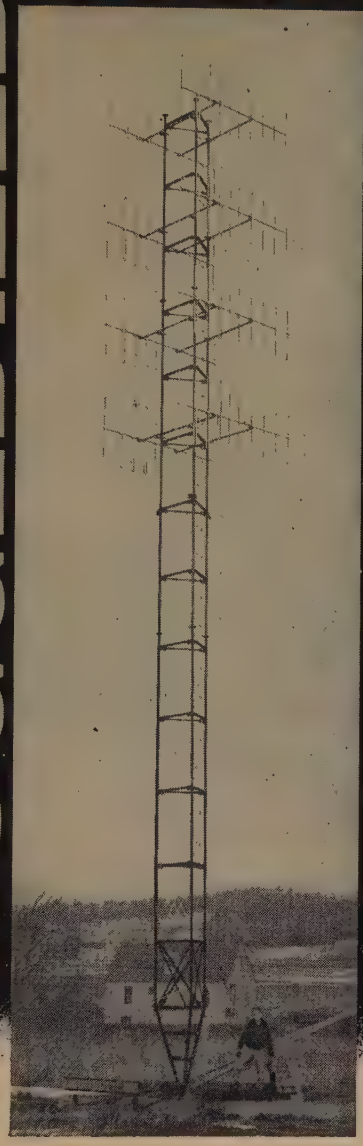
EPHEY JOINS AIL AS MANAGER OF MILITARY SALES

Harry M. Stephey has been named nager of Military Sales of Airborne truments Laboratory (AIL), Long Is- d, N.Y., a division of Cutler-Hammer, In this capacity he will direct the vities of the company's military field s organization, headquarters sales sales administration.

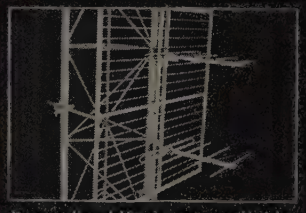
(*Continued on page 12*)

Circle Reader Service Card 7

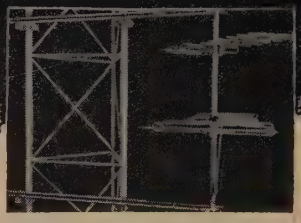
RUGGEDIZED YAGIS for communications



Taco Ruggedized Yagis are specifically designed to meet the performance parameters of the industrial and defense user. They are built to provide the highest electrical performance under all weather conditions. Tubing is ⅝" OD 6061T6 high strength aluminum alloy, reinforced with ¾" OD telescoping sleeves at points of greatest stress. The antenna is of welded construction. Transmission line termination is a coaxial connector. The connector housing is filled with foamed plastic to eliminate condensation.

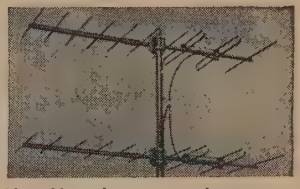


Ruggedized Yagis are available with screen-type reflectors, as single units or arrays of 2, 4, or more antennas.



All types of mounting hardware are standard accessories, for both vertical or horizontal polarization.

Taco Ruggedized Yagis are available in many models for various operations from 30 MCS to 500 MCS. Hardware is available for stacking two or more units of any model for additional gain. Power handling capacities range to 750 watts for single units, which may be raised through stacking arrays. Gain, directivity patterns, and front-to-back ratios are excellent, varying in characteristics according to the particular model chosen.



Mast-Mounting accessories assure positive azimuth positioning and dependability.

Write for complete details, including all mechanical and electrical specifications...

TACO DEFENSE & INDUSTRIAL DEPT.

TECHNICAL APPLIANCE CORPORATION, Sherburne, New York.

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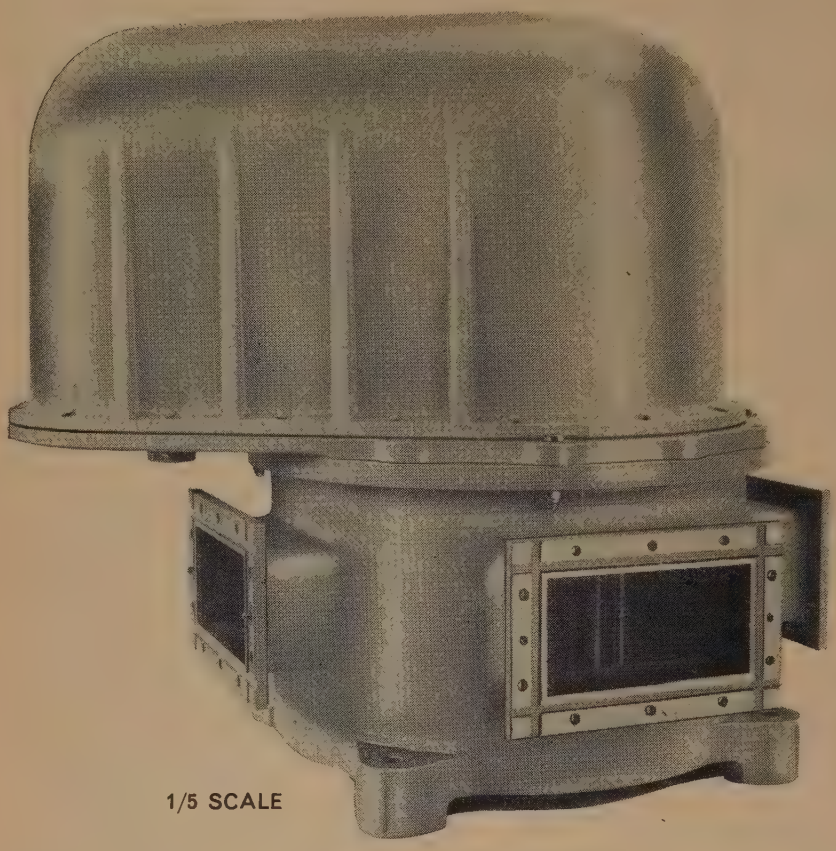
SPLIT



1/5 SCALE

PERSONALITY

IT'S BIG! Our new high power L-Band Switch has a waveguide cross section of 3¼" by 6½". It provides quite high electrical isolation between the two RF channels. Minimum guaranteed isolation is 80db. Air pressure can be maintained in one RF channel while the other channel is unpressurized. It maintains pressurization during the switching cycle when it automatically shuts off one transmitter and turns on the second transmitter as soon as the VSWR is in the proper limits. In the normal operating position, this new Airtron Switch has a VSWR of less than 1.10. Send today for complete specifications.

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GENERAL OFFICES MORRIS PLAINS, N.J.

Circle Reader Service Card 9

Industry News

(*Continued from page 11*)

A graduate of Drexel Institute o Technology with a B.S. in E.E., Mr. Ste phey served from 1949 to 1957 as gov ernment sales manager of Governmen and Industrial Division, Philco Corp During the past three years he has bee with the General Electric Company most recently in Philadelphia as man ager of Defense Requirements, Missi and Space Vehicle Department.

— m w j —

HUGHES AIRCRAFT SETS UP TWO NEW TUBE DIVISIONS

Two new divisions of Hughes Air craft Company have been establishe for the development, production an marketing of commercial vacuum tub devices, according to Iden F. Richard son, Hughes Products Group manage

They are the Microwave Tube divisio and the Vacuum Tube Products divisio

The Microwave Tube division wi consolidate all existing research, deve opment and manufacturing facilities no engaged in microwave tube activities u der one management. Dr. Lester M Field, formerly associate director Hughes' research laboratories, has be named manager of the new division.

The Vacuum Tube Products divisio will produce the company's line of sp cial purpose cathode ray storage tub special cathode ray tubes, power an rectifier tubes, vacuum tubes and gaug and welding equipment. James J. Suth land, previously marketing manager the former Electron Tube division, h been named manager of Vacuum Tu Products division.

— m w j —

(*Continued on page 30*)

Ready for you now!

Primary standard accuracy for power measurements to 1,000 watts!

Sierra 290B Test Set

Frequency coverage dc through 12.4 KMC.

Guaranteed power measuring accuracy of 1%. Probable accuracy better than 0.5%. Precise ac wattmeter, calorimeter and heat exchanger in one neat, rack unit. Separate dual loads for dc to 4 KMC, also C, XB, X bands. Direct reading linear scale.

Above are highlights of the new Sierra 290B Calorimetric Wattmeter Test Set—the industry's closest approach to absolute power measurements in this range.

Model 290B measures power in three distinct modes.

1. For power levels 30 to 1,000 watts, a null-balance mode provides measurement accuracies of 1% or better, with probable error as low as 0.5%.

2. For wider range power levels from 10 to 1,500 watts, a direct-reading mode provides excellent linearity in thermal readout and 2% to 3% accuracy. Readout is fast—60 seconds or less.

3. For expanded scale readings of highest resolution, the above two modes may be combined in a third mode to obtain the order of accuracy of the null-balance mode, together with the time-saving convenience of the direct readout mode.

Model 290B, $4,500.00. (Water loads, extra.)

Data and prices subject to change without notice. Prices f.o.b. factory.

Laboratory setup above shows Sierra Model 215 Power Source being used in conjunction with Model 290B Calorimeter to calibrate Sierra Bi-Directional Power Monitor. Designed specifically for calibration purposes, 215 series Sources include four 50 watt models covering, collectively, 25 to 1,000 MC. Model 215A, 25 to 50 MC; Model 215B, 50 to 150 MC; Model 215C, 150 to 470 MC; Model 215D, 470 to 1,000 MC. Price (any model) $3,300.00.

For complete details, see your Sierra representative or write direct

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sierra

Look at the maximum, low over-all receiver noise figures they make possible:

8.0 db in "L" band . . . 1N25B, 1N25RB
6.0 db in "S" band . . . 1N21F, 1N21RF
7.0 db in "X" band . . . 1N23F, 1N23RF
7.5 db in "Ku" band . 1N78D, 1N78RD
9.5 db in "K" band . . 1N26C, 1N26RC
9.0 db in "Ka" band . 1N53C, 1N53RC

ELECTRICAL CHARACTERISTICS (25°C)			
SYLVANIA DIODE	ONF (Max. db for $N_{if} = 1.5$ db)	L_c (Max. db)	N_r (Max. ratio)
1N25B, 1N25RB	8.0	5.5	1.5
1N21F, 1N21RF	6.0	—	—
1N23F, 1N23RF	7.0	—	—
1N78D, 1N78RD	7.5	5.7	1.3
1N26C, 1N26RC	9.5	7.5	1.5
1N53C, 1N53RC	9.0	6.5	2.0

NOMOGRAPH FOR COMPUTING OVER-ALL NOISE FIGURE

Cat's-paw quiet...

Sylvania Microwave Low-noise Mixer Diodes

for radar, relay, and communications systems

Sylvania Low-Noise Diodes are manufactured to conform to Mil specs. All are immediately available. Design around Sylvania Microwave Diodes. You'll shout about the low-noise figures of your equipment. Contact your local Sylvania Field Office for sales information. For technical data, write Semiconductor Division, Sylvania Electric Products Inc., Dept. 356 Woburn, Massachusetts.

SYLVANIA

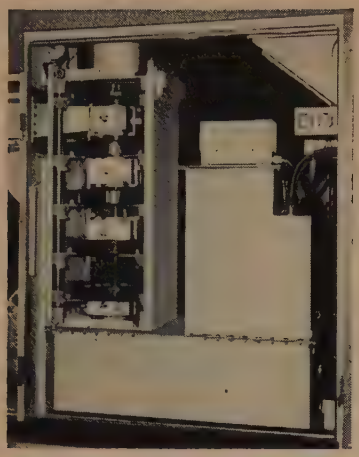
Subsidiary of **GENERAL TELEPHONE & ELECTRONICS** GENERAL SYSTEM

Combining microwave design, manufacturing, test and research, the integrated services of Gorham Electronics reflect the vastness of the microwave field itself. If your problems span this field we welcome you to call upon

Gorham
ELECTRONICS

Write for your copy of this brochure! A few moments reviewing the services of Gorham Electronics' and our wholly owned subsidiary Pickard & Burns, Inc. will be time well invested.

DIVISION OF THE GORHAM MANUFACTURING COMPANY, PROVIDENCE 7, RHODE ISLAND

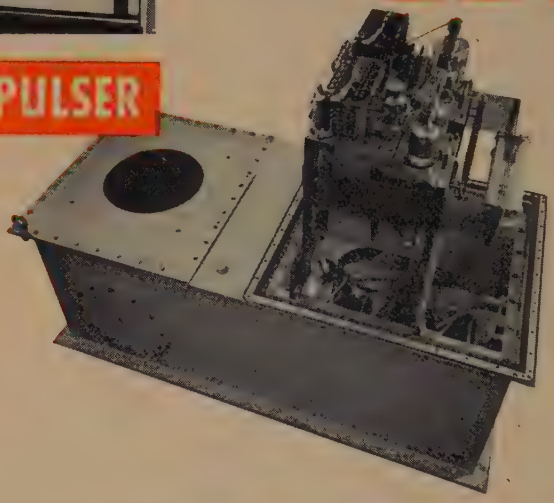


HIGH-POWER R-F PACKAGES...

done by the old mil specs

and LEVINTHAL

BENDIX PULSER



These photos indicate the degree to which our engineering and manufacturing groups feel at home with military specifications.

For Bendix Radio we are supplying 12 copies of a floating-deck modulator for AN/FPS 30 "Sentinel" Radar. For Motorola we are just completing a communication and control-system transmitter for the Sage program. We have also designed and built the modulator and power supply for the U.S. Marine Corps AN/MPS 21 Piggyback Radar System, under subcontract to Sperry; and the transmitter for the Azusa Radar, under subcontract to Convair.

MOTOROLA TRANSMITTER

You are invited to consider the possibilities of continuing your professional advancement with Levinthal Electronic Products. Your resume should be sent to the personnel manager, Bert Carpenter.

All these and more have been designed and built to full military specifications in the Levinthal plant. Your needs in this area can be met here too.

Why not call and discuss them with Bob Johnson, our applications engineering manager?

LEVINTHAL ELECTRONIC PRODUCTS

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SUBSIDIARY OF RADIATION INCORPORATED

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Over 800 products developed and manufactured by Microwave Associates are covered in the short-form catalogs of our three Divisions. Excellence in research and development is bringing many more products. We will gladly register your name to receive these catalogs and technical information on all new Microwave components. In addition to these short-form catalogs, over 300 pages of useful handbooks, theory and applications brochures, and detailed catalogs are available

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Two hundred TR tubes, duplexers, magnetrons, ferrite devices, modulators, limiters, switches, and other new and specialized microwave electronic tubes.

PLEASE SEND ME UP-TO-DATE INFORMATION ON THE PRODUCTS IN THE AREAS INDICATED.

Name (please print or type)

Title

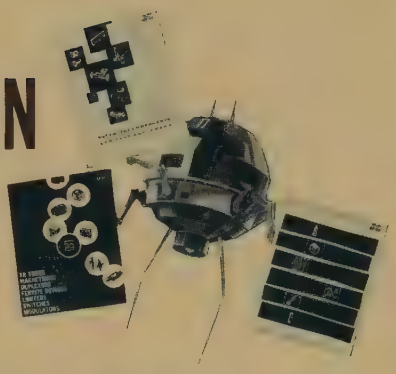
Company

Address

City Zone State

Note: YOU MAY ALREADY BE ON OUR MAILING LIST. IF SO, PLEASE DO NOT MAIL THIS REQUEST.

TEN YEARS OF MICROWAVE LEADERSHIP



Microwave Associates . . . at the ten-year mark . . . is a leader in each of three major microwave areas — Specialized Microwave Electronic Tubes and Ferrite Devices — Silicon Semiconductors — Custom Waveguide Components, Test Equipment, and RF sub-systems.

Six hundred employees exercise specialized microwave know-how in two completely modern plants covering more than 2½ acres of research and manufacturing space. Whether your requirements are for individual components, sub-system assemblies, or for research and development leading to them, Microwave Associates has the experience, modern facilities, and financial resources to guarantee your complete satisfaction.

Microwave Associates is represented throughout the United States by more than 20 authorized representatives, and overseas by Microwave International Corp.

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NEW TOOLS FOR RESEARCH

DR. BENJAMIN LAX
Associate Editor
the microwave journal

Major advances in science are inevitably attributed to formulation of a new theoretical concept or the dis- ry of a new physical phenomenon. These events are lly accompanied beforehand or in retrospect by some conceived basic experiments. The realization of these riments depends strongly on the state of the art and nology. Sometimes it becomes necessary to develop tools to solve such novel and challenging problems. his respect, the creation of these tools becomes a double- d sword. Not only does it permit the solution of the inal problems, but it opens up new vistas and stimu- experimental ideas whose conception was psychologi- prevented by the absence of the means which would nit its execution. It is this aspect of research that we ld like to explore in this editorial.

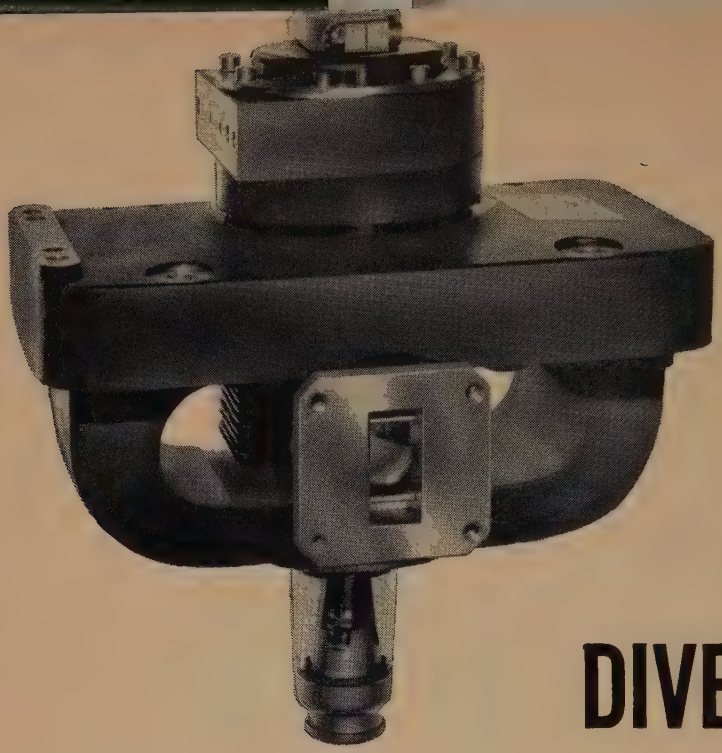
efore we delve into the subject of the tools of the re, it is appropriate to mention a few developments in own generation which have played a dominant role in nding our knowledge of the universe and of the ma- ls which compose it. One could very readily demon- e the point by reviewing some of the historical de- pments of the microwave field. Physicists in the early ies were quite aware of the golden opportunities that within their grasp where the instruments were de- ped that would permit them to generate radio waves in egion of the electro-magnetic spectrum which we now nicrowaves. The discovery of the klystron and the mag- on made this dream a reality. The wartime develop- of radar was the immediate consequence of these dis- ries. Peacetime activities such as radiometry and radio nomy were the natural consequence of the advances were achieved in the wartime effort on radar.

icrowave spectroscopy as a research tool for the study ases and solids is also a post-war phenomenon that has had an explosive growth which can be characterized by the term, "The golden era of microwave physics." But even here, particularly where solids are concerned, there were a number of new tools or techniques that played as important role as those associated with the microwave technology itself. Among these, one of the most significant was the timely invention of the helium liquifier which has permitted low temperature exploration of resonance phenomena at microwave frequencies. Of course along with the microwaves and the low temperature techniques, the simultaneous evolution of a materials science was also a major factor in this phenomenally rapid exploitation of solid state. The invention and development of the solid state low noise amplifier is a relatively recent phenomenon which illustrates this point in question. Masers and parametric amplifiers have opened up new dimensions and new possibilities for radar, radio astronomy, and communications that are most appropriate for the present space era.

The new tools which I want to discuss at this particular time are in many ways as revolutionary as those which had their tremendous impact on microwave research during the last two decades. Their potential is not only significant for the field of microwaves, but for other areas of science as well. The use of extremely high pressures, high magnetic fields, ultrasonic waves at microwave frequencies and the combination of optical and microwave techniques will provide opportunities for physicists and engineers which are comparable to those described in the preceding paragraph. Let us consider each of these separately and see how they can extend our basic knowledge of materials, natural and synthetic.

Extremely high pressure techniques are not really new and have been the object of extensive research by the Nobel

(*Continued on page 21*)



NEW MAGNETRON FOR RELIABLE FREQUENCY DIVERSITY RADAR

Frequency diversity and higher definition airborne radars are achievable with a new Litton Industries X-band hydraulically tunable Magnetron.

This tube is another in the growing family of hydraulically tuned pulse Magnetrons we introduced two years ago for new equipment and retrofit frequency diversity requirements.

Designated the type L-3305, this Magnetron can be tuned at rates up to 100,000 megacycles per second over the frequency range of 8600 to 9500 megacycles. Pulse stability at peak power output in excess of 65 kilowatts is maintained while the tube is tuned at these extremely rapid rates.

The design and capability of this tube reflect our experience as a major supplier of thousands of hydraulically tuned CW Magnetrons for countermeasures. The ruggedized design permits application of the L-3305 Magnetron where severe shock and vibration conditions may exist. The hydraulic actuator is an integral part of the tube design, resulting in smooth, positive tuning action. Provision is made for the adjustment of the hydraulically controlled valve directly to the actuator, insuring nearly zero error, maximum reliability and ease of maintainability. Flexibility of system design is possible since the compact power supply and reservoir system may be remotely located.

Reliability, long life both in-service and on the shelf and immediate full power operability at any time are built-in features of this exactingly constructed tube.

We will gladly send you additional information, if you will write to Litton Industries, Electron Tube Division, Office M-13, 960 Industrial Road, San Carlos, California.

LITTON INDUSTRIES **Electron Tube Division**

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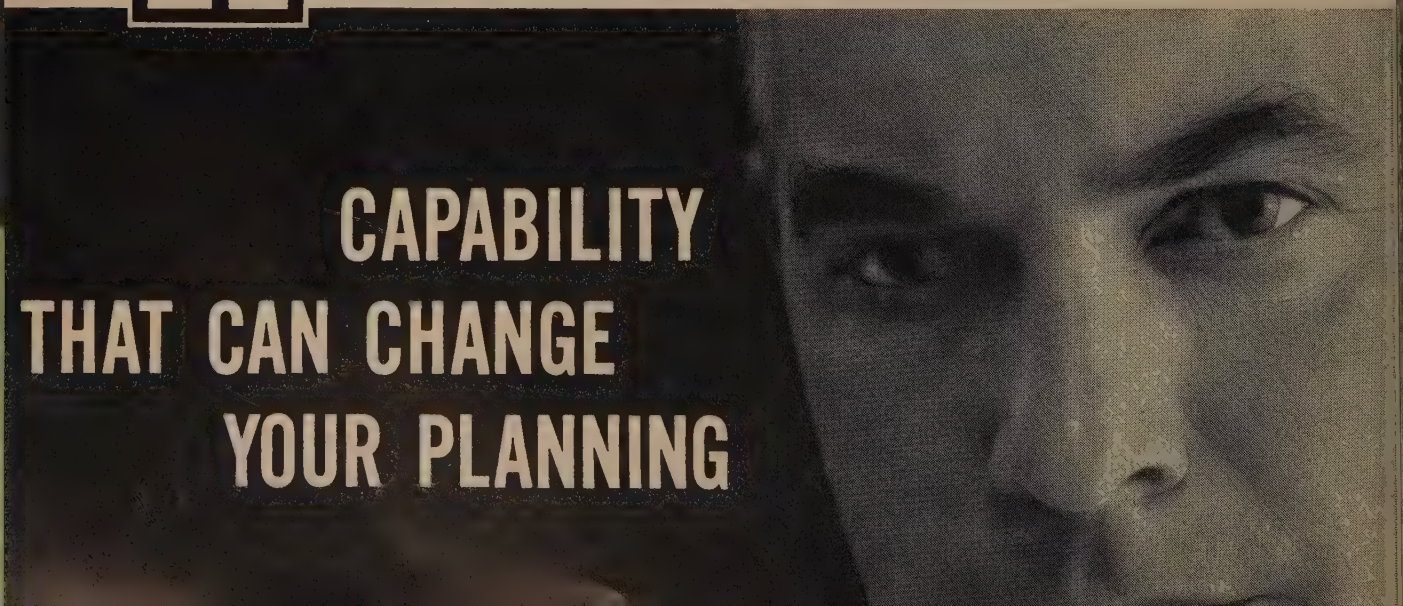


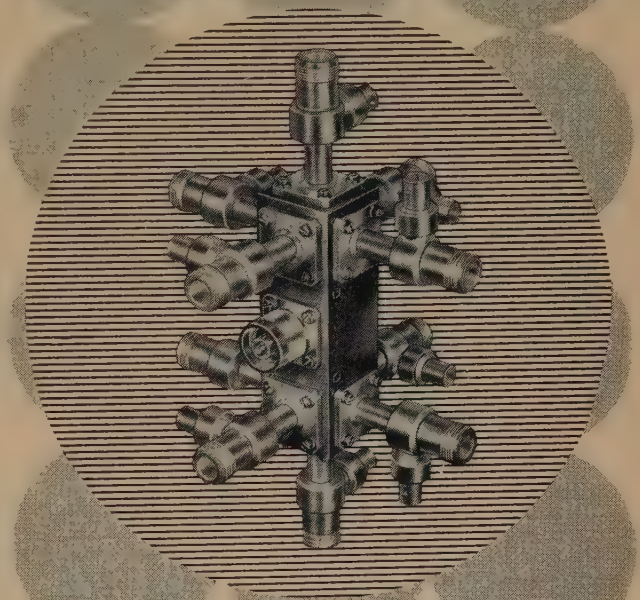
Benjamin Lax

(*Continued from page 19*)

eate, Bridgman, at Harvard University. What is new
ıt them is that some of the techniques have now been
nded to include a wider variety of physical measure-
ts which should permit the incorporation of more
lern techniques, such as microwaves for fundamental
ies. High pressures combined with high temperatures
only permit the preparation of such exotic materials as
ıond borizon — a synthetic material of boron and ni-
en — but a host of others which should increase the
er of our galaxy of materials whose use in our tech-
gy, both for basic investigations and applications, will
ome more and more significant. High pressures like
r externally applied forces permit us to alter the state
natter as it is increased from a few atmospheres well
several hundred thousand. Crystals actually go through
se transformation and take different forms; metals not
change their physical, but also their electrical proper-
The change in pressure can be used as a parameter for
lying the electronic and optical properties of semi-
ductors, magnetic and other materials. Microwave and
lear resonance have now been observed in materials
er relatively high pressures showing very interesting
cts upon the magnetic properties of electrons and
lei in a solid in a varying crystallographic environment.
our ability to handle these tools is increased, we should
able to develop better windows for the study of the
cal properties of matter, at higher pressures than here-
re, and over a wider range of the electro-magnetic spec-
n from the millimeter into the optical range. Such tech-
ies will make it possible to observe more directly the
sitions that take place in the energy structure of solids
ther they be associated with quasi-continuous levels, i.e.,
gy bands as in semiconductors and in metals, but also
rete levels such as those encountered with impurities or
erfections in semiconductors and those of magnetic
in a variety of host crystals. The modern high pres-
instruments using the tetrahedral anvil or others per-
the application of pressures with symmetry properties
ch are of lower order than those of the hydrostatic type.
s in turn can remove some of the degeneracies inherent
rystals of high symmetry. Thus the complexity of the
tromagnetic spectrum becomes greater, but so is the
rmation conveyed about the basic properties of these
erials and the impurities within them.
High magnetic fields again follow a pattern which is
ogous to that of high pressures. This is not really a
endeavor since people like Kapitza and Bitter have
neered in this area in the twenties and the thirties. The
ner has built pulse magnets which were capable of
hing approximately 500,000 gauss and the latter DC
ls in larger volumes as high as 100,000 gauss. Today,
n modern technology and the equally modern pocket-
k, it appears that these can be exceeded by about a fac-
of two or more not only in intensity, but also in total
me. Furthermore, the potential use of such tools for
arch in plasmas, solid state and low temperatures her-
a new era wherein many new phenomena can be in-
igated and in addition some old phenomena can be
ored at higher fields and therefore with greater resolu-

(*Continued on page 22*)

NEW
SOLID STATE
MICROWAVE
COMMUTATOR
SINGLE POLE MULTIPLE THROW COAXIAL
SOLID STATE (CRYSTAL) SWITCHES
in
SPST—SPDT—SP4T—SP10T (shown in Photo)
OR ANY OTHER CONFIGURATION ON SPECIAL ORDER



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Dr. Benjamin Lax

(*Continued from page 21*)

tion. For instance, in solid state spectroscopy, whether it be in the microwave region or elsewhere in the electromagnetic spectrum, the use of higher frequencies under appropriate conditions means an increase in the resolution of our system. Often the limit that has been imposed in the past for resonance experiments in paramagnetic, ferromagnetic or antiferromagnetic materials has been that of the intensity of the magnetic field available to the researcher. Consequently, it is not surprising that most resonance spectrometers went no higher than approximately 25,000 megacycles which for the usual electron spin requires fields slightly in excess of 10,000 gauss. However, the extension of such resonance experiments to one or two millimeters would require magnetic fields in excess of 100,000 and 500,000 gauss respectively in a volume sufficiently large to accommodate a high Q resonance cavity, and the liquid helium dewar as well. The conventional electromagnet has not been adequate. Cyclotron resonance in semiconductors and metals, a relative newcomer to the microwave field, has had only limited success with a few well-chosen materials at these frequencies. However, in order to extend these to many other materials, it soon became apparent that the solution lay in the use of higher frequencies from the millimeter to the infrared, thereby increasing the frequencies by one and two orders of magnitude. Similarly, antiferromagnetic resonance in many materials occurs in internal fields which is essentially a geometric mean between the internal exchange fields and the anisotropy field. The former can be several million gauss and the latter of the order of maybe a few thousand to 10,000 gauss. The effective field, itself therefore, can be anywhere from 100,000 gauss and higher. The natural resonance, then, occurs in the millimeter and submillimeter or far infrared region of the spectrum. This is a rather difficult region to work in. However, with the use of high magnetic fields, it is possible to tune one mode of resonance by opposing the internal field and reducing the net effective field so that the resonance occurs in a more comfortable region of the millimeter or microwave spectrum. Some preliminary experiments, in both cyclotron resonance and antiferromagnetic resonance have already been carried out with pulse magnetic fields capable of going as high as 300,000-400,000 gauss. One of the most interesting new results obtained with the pulse field technique was cyclotron resonance in indium antimonide, and for the first time in the metal bismuth *both at room temperature* and at infrared wavelengths of 10 to 20 microns.

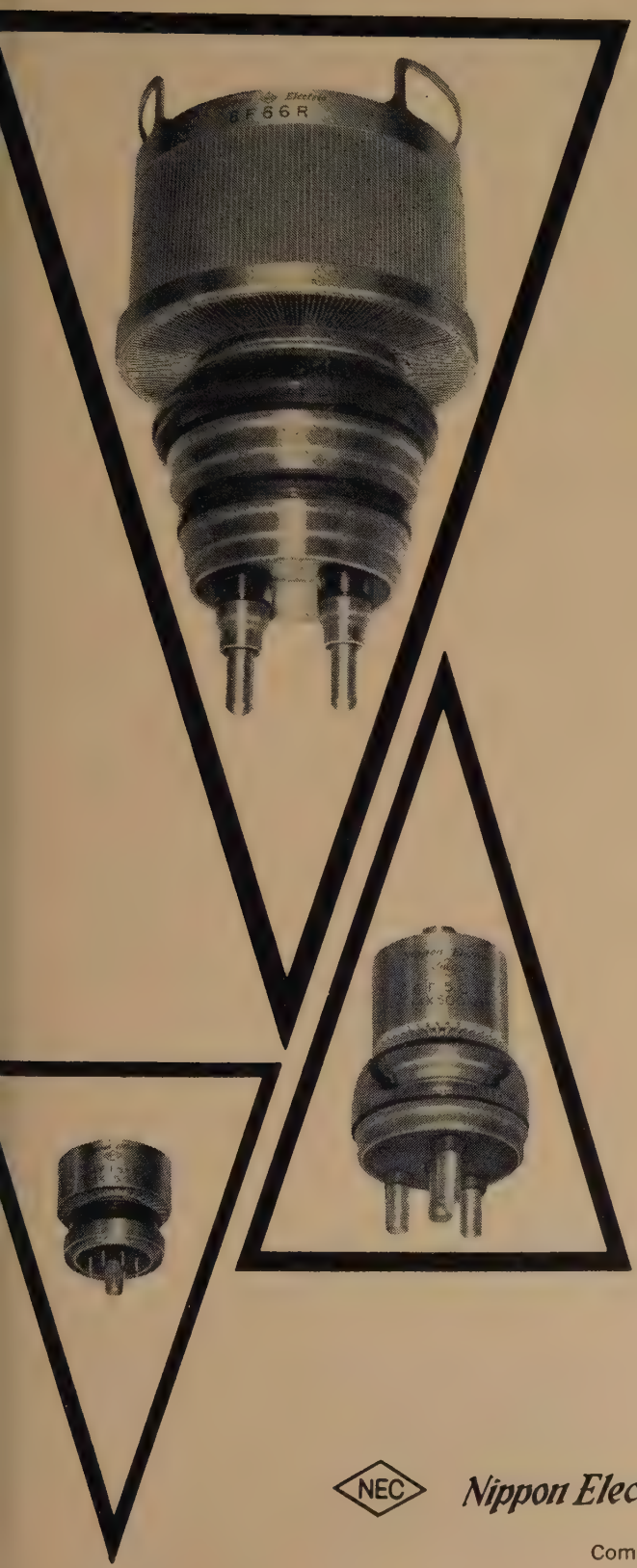
These pulse or transient measurements of course have limitations and disadvantages which can and will be overcome by the use of continuous magnetic fields. It appears that within the limit of our present capabilities it will be possible to extend these to approximately one-quarter million gauss. This then should permit such resonance experiments to be carried out in the submillimeter and the far infrared region where the spectrum is energy limited. The advantage of course will be that phase detection methods will be possible providing greater sensitivity and resolution. Indeed, some experiments along these lines have already been carried out at 2 millimeters using the Bitter air core solenoid magnet at M.I.T. Undoubtedly many other similar phenomena will eventually be tackled by this combination of high fields and higher frequencies. However, even the microwave range of the spectrum can hope provide new results with the benefit of the large solenoi magnets. It has been shown theoretically that some se conductors and other materials contain spins whose effect magnetic moment along certain directions are much l than that of the free electrons and therefore resonance curs at a higher field. Similarly, solids like the alk halides have effective masses associated with the electro motion within the solid which are greater than that of free electron so that cyclotron resonance at microwave f quencies also requires much higher fields than those p vided by the conventional electromagnet. Hence, in or to observe either of these types of spectra in their full co plexity, the higher fields are required to both resolve a observe the spectrum in the first place.

Another area where the high magnetic field will equally effective is in the study of the optical properties solids. Even at relatively lower fields of the order of 30,0 40,000 gauss, new and interesting phenomena have b observed in semiconductors, metals and also in solids w magnetic impurities, indicating a tremendous potential fields of greater intensity. The magnetic fields serve a t fold purpose in many such experiments. In actuality, a m netic field represents a uni-axial configuration which effect lowers the symmetry of the electronic properties the crystal and thereby removes some of the degenera associated with a crystal of higher symmetry. Secon since the magnetic field can be rotated relatively to crystalline axes, the anisotropy identifies the detailed pro ties associated with the crystalline symmetry. In additi a spectrum which is highly complex and has many-fold generacies often requires the higher fields for proper re lution. The magnetic field does one more thing as in se conductors and metals, it introduces quasi-discrete le for electrons and holes which did not exist before thereby permit the exploration of the electronic proper of the carriers in energy states or bands not possible the more conventional microwave or millimeter techniq The lists of possibilities for intense magnetic fields in p ma physics, low temperatures and electronic applicati can be discussed in equal detail, not to mention ma possibilities undoubtedly lurking in the unknown, but s to unfold in the future.

The third item of interest to our theme is the use ultrasonics at microwave frequencies. This is perhaps of the most recent developments of those mentioned. Te niques have been developed which allow the coupling electromagnetic energy in a re-entrant microwave ca into a quartz rod inserted into it, which then by pie electric coupling induces ultrasonic waves in the quartz at the same microwave frequency. One of the already st ling results has been the observation of spin resonance such a quartz rod by these techniques. Since this field research is so new, it is interesting to contemplate jus few possibilities for its use. It is known already that lower frequencies such ultrasonic waves in the UHF reg have been successful in exploring the electronic proper of some metals. A new kind of geometric resonance clo related to cyclotron resonance has been observed. Th retically it can be shown that true cyclotron resona should also be observable in metals at microwave frequ cies by this method. The possible advantage of this t

(*Continued on page 24*)

VHF beam power tetrodes



Each of the following NEC tubes is a direct replacement under all circumstances for the corresponding type.

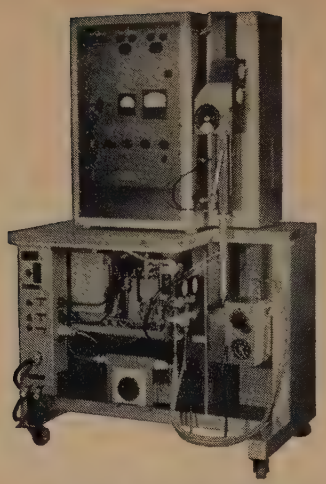
NEC type	Type To Be Replaced	Cathode/ Filament Volts	Grid-Screen Mu-Factor	Max. Plate Ratings	
				Volts (D.C.)	Dissipation (Watts)
4F15R	4X150A	6	5	1,250	150
6F50R	4X500A	5	6.2	4,000	500
8F66R	6166	5	10	6,000	10,000

Production of high-power transmitting tubes began at NEC in 1933. A number of "firsts" marked these early years: 1933, first 15 KW short-wave transmitter tube; 1934, first 100 KW standard broadcast tube; 1938, first 50 KW short-wave transmitter tube. In recent years, NEC has been following designs of U.S. Manufactures and concentrating on improving tube life.

The most important improvements have been a new doped-nickel cathode material with high emission at low oxide evaporation rate, and non-sag thoriated tungsten filament material which has completely eliminated filament-grid shorts. NEC considers the life characteristic of its electron tubes to be among the most favorable in the industry.

NEC *Nippon Electric Company Limited.* Tokyo, Japan

Components / Systems



UNIQUE VERSATILE COMPLETE microwave dielectrometer

Measures dielectric constant and loss over a wide temperature range at 1, 3, and 8.5 kmc.

With a complete line of accessories the Central Research Laboratories Dielectrometer gives high accuracy and unequalled versatility.

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For brochure giving details and specifications, write:

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Dr. Benjamin Lax

(*Continued from page 22*)

nique over that of the conventional electromagnetic co ling to metals is that the latter has a finite skin depth penetration into the metal which is of the order of a microns. This makes the resonance have an anomal character at low temperatures. However, since it is c ceivable that the ultrasonic waves can penetrate m deeper into the bulk of the crystal that cyclotron resona can be observed in metals in its true form at microw frequencies. Another interesting possibility is the devel ment of a more sensitive paramagnetic or spin resona spectra using the acoustical waves. If this can be don should be possible to examine host crystals with sma magnetic impurities by several orders of magnitude t heretofore. In some of these solids and in semiconduct complex spectra could be observed with much gre resolution, thus providing an opportunity to study rela tion phenomena and also fine structure under more fav able conditions. One other phenomenon which has b observed and which illustrates the usefulness of ultraso at microwaves is the coupling of these waves in a fer Such investigations in solids can possibly provide the n essary clues for explaining the physical interaction betw the magnetic dipoles and electrons with the crystal latt

Although optical investigation of solids has been go on for a long time, the idea of combining this with mi wave techniques is relatively new. Perhaps one of reasons for this is that low temperature optical spectra solids is also of recent vintage. The narrow lines obtai at liquid helium temperatures permit separation wh falls within the microwave range of energies. Under th conditions it has become fashionable to consider opt pumping in solids as a possible energy source for ma operable in the millimeter and infrared regions of the sp trum. Alternatively, since detection of optical absorp in a solid can be relatively easily accomplished, this serve as a very sensitive detector for microwave resona absorption in dilute paramagnetic crystals. Perhaps one the most promising areas where optical and microwave millimeter techniques will be very fruitful is for cyclot resonance measurements. Actually in semiconductors, o cal excitation of carriers either from an impurity level across the energy gap has been standard for cyclot resonance from its inception. Indications of some er sions at microwave frequencies by holes in germani has already been observed. The possibility of detect resonance of holes and electrons in higher energy ba presents a very exciting prospect for fundamental vestigation. But perhaps the most attractive prize of al this regard is that if cyclotron resonance masers can developed they should be capable of operating from microwave into the infrared region, a portion of the e tromagnetic spectrum where the energy is extremely A good coherent source in this region would provid tool for research that would create the kind of scien revolution that would indeed illustrate the thesis of editorial.

Mr. Jarvis is president, Dr. Lacy vice ident and director of engineering, Mr. Dunwoodie director of new duct development. In addition to r education Wiltron Company's three nders have a combined 22 years ex- ence in their field.

he company plans to do sponsored elopment work in the field of fast RF e testing of microwave tubes, the ing of high resolution radars and of computers and switching compon- . It is believed that this will be the company to provide a blend of mi- vave and video pulse techniques and concentrate only in this specific area.

Mr. Jarvis received his BS Degree n the U.S. Naval Academy at An- olis and an MBA from Stanford duate School of Business. He did r college work at the University of ahoma, the University of California for the last 6 months engaged in duate studies in Electronics Engineer- at Stanford. Mr. Jarvis was with vlett-Packard Company for six years re he was in charge of special in- ments and systems; he most recently engaged in product planning for instruments.

Dr. Lacy received his BSEE Degree n Florida University and following duation served for a short time as ructor there; his MS and PhD De- s are from Stanford University where did research in microwave noise in tron beams. He served for a year as sultant to Varian Associates. For the 10 years Dr. Lacy has been a mem- of the Hewlett-Packard laboratory, t recently being senior member of advanced development section.

Mr. Dunwoodie received his BSEE ree at Kansas University and his MS ree at Stanford. He is now complet- work at Stanford for an advanced ee of Engineering. His engineering erience is also from the Hewlett- ard laboratory, where he served for years. He has been project leader the development of commercial and tary electronic instruments.

—mwj—

(*Continued on page 32*)

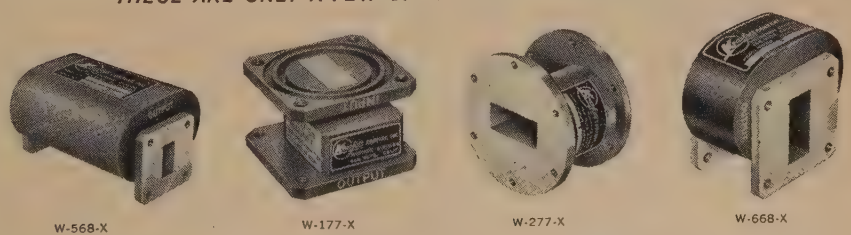
MICROWAVE Kearfott PRODUCTS

FERRITE ISOLATOR

The all new Model WD-2106 Octave S-Band Isolator marks a revolutionary advancement in the microwave field by permitting the use of only one isolator for a full octave frequency range instead of covering the band in increments using a number of isolators. Ideal for use in telemetry, radar systems and transponders, the new unit offers exceptional reliability, excellent isolation to insertion loss characteristics and compactness of design.

TYPICAL SPECIFICATIONS				
MODEL	FREQ. RANGE	ISOLATION	INSERTION LOSS	V.S.W.R.
WD-2106	**2.1-4.3 KMC**	**20 DB Min.**	**2.0 DB Max.**	**1.5 Max.**
W-568-3A-2	12.5-18.0 KMC	20 DB Min.	1.0 DB Max.	1.15 Max.
W-177-1K-1	9.5 KMC ± 100 MC	25 DB Min.	.7 DB Max.	1.15 Max.
W-277-3A-3	5.2-5.9 KMC	17 DB Min.	1.0 DB Max.	1.15 Max.
W-668-1A-2	8.5-9.6 KMC	10 DB Min.	0.4 DB Max.	1.10 Max.

THESE ARE ONLY A FEW OF THE MANY AVAILABLE MODELS



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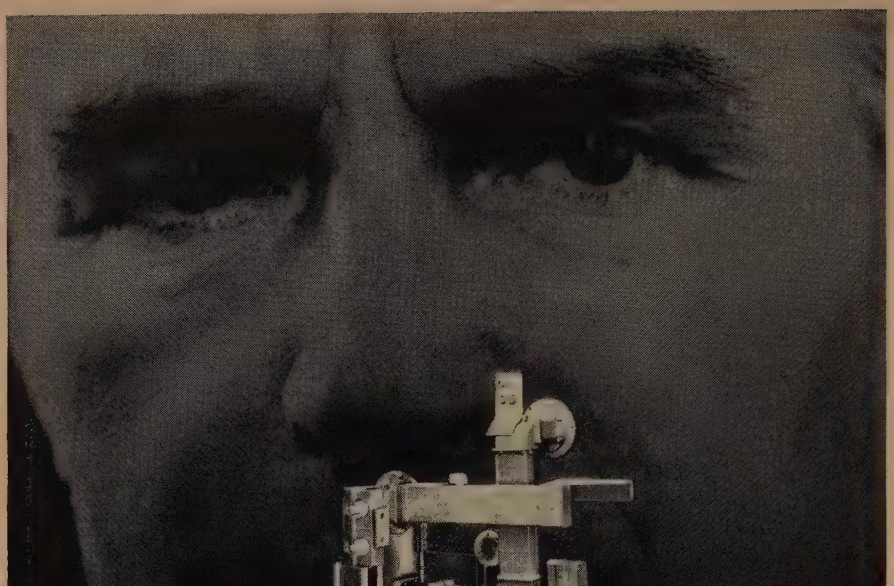

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Ask a dozen engineers, purchasing executives or designers . . . and get a dozen different answers. Is performance measured in cost, delivery date, or design assistance? Certainly the true measure of performance is a satisfied customer. And this comes from more than plant or personnel, production men or sales staff. Satisfied performance springs from companies that function as a team . . . efficiently. These companies lay their reputation on the line with every contract and every delivery.

Budd-Stanley is this kind of company . . . a tightly knit, highly efficient team with a reputation for delivering what we promise on the promised date. And at Budd-Stanley, in one plant, you'll find America's most complete facility for every waveguide application. Facilities brochure available upon request. Consider calling us in on your project . . . whether it be for product design, prototype, or production run.

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for every waveguide application

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Industry News

(Continued from page 31)

WAVEGUIDE PRESSURE WINDO CATALOGUE

A new 12 page catalog descri waveguide pressure windows, their plications, and installation suggestion available from Microwave Associ Inc., Burlington, Mass.

Outline drawings, dimensions, ph and complete electrical and mecha data are given. Window types covere this catalog include Flange-Mou MICA windows; Solderable Glass-K Windows; (Including those with a Flex-Frame construction — high press low-power, narrow band applicatio Flange-Mounted Glass-Kovar Wind (Triple and Single Iris); Solder Flange-Mounted Windows; and Pres Window — Waveguide Assemblies.

Pressure windows described in the crowave Associates catalog are desig to serve increasing power handling quirements over wide temperature ra

The waveguide pressure windows ly propagate RF energy over a spe bandwidth of frequencies and seal sections of waveguide in radar or c microwave waveguide applications w pressure, humidity, and dust seals ar quired.

— m w j —

ANTENNA SYSTEMS ERECTS NE PRECISION 30-FOOT ANTENN

Antenna Systems, Inc., Hingham, M announces it has erected the first pro tion 30-foot parabolic antenna. This s surface antenna, designed and built ASI, is a production job with i changeable parts and can be mass duced at low cost. It's rugged and h ly versatile, can be used at any frequ up through X band, can be used wi cassegrain reflector, and can accommo a variety of aluminum or fiberglass configurations. It is easy to erect, for shipping compactness, all fra break down into plane trusses or si members which can be easily transpo for field survey work or mobile sc systems.

President Creaser announced that antenna is our first proprietary item, is proof of our ability to pioneer vances in the antenna field." Al Fo manager of Marketing said, "We ar lighted with the finished product. accuracy of the reflector surface and of assembly has more than justified investment in careful design and p sion tooling."

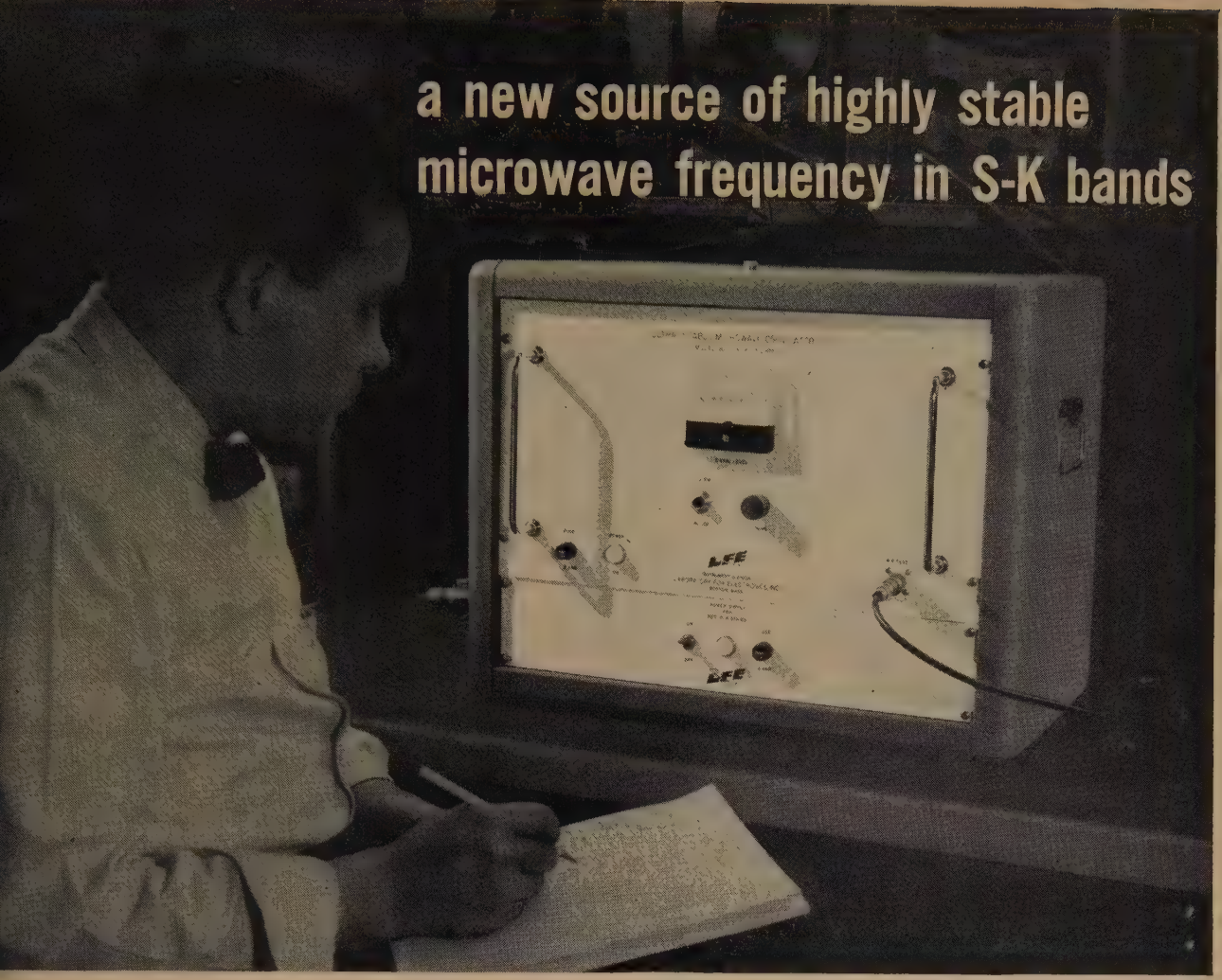
— m w j —

ROE APPOINTED MANAGE AT AIRTRON'S NEW JERSEY PL

J. Robert Roe has been appointed ager of the Morris Plains, N.J., m wave components product line of tron, a division of Litton Industries cording to William F. Boyd, vice p dent and general manager of the divi

(Continued on page 34)

a new source of highly stable microwave frequency in S-K bands



Introduced at the 1960 IRE Show, LFE's 820-XLK Series offers a new "state-of-the-art" approach to fixed microwave frequency stability.

Utilizing a klystron locked to a quartz crystal through a unique multiplier chain and IF loop, long term stability of 1 part in 10^6 is achieved over a 24 hour period. Incidental FM is reduced to only 1 part in 10^8. Although considered a secondary standard, the order of stability approaches that of a primary source.

Applications include microwave frequency calibration, parametric amplifier pump sources, radio astronomy, high resolution radar and in research and development programs where low incidental FM and excellent long-term drift characteristics are required.

Write for complete specifications and prices.

SERIES 820-XLK
KLYSTRON LOCKED OSCILLATORS

Model	For fixed frequence in range of: (see note 1)
820-XLK-S-f*	2500 to 4000 mc
820-XLK-C-f*	4000 to 6500 mc
820-XLK-X-f*	6500 to 12,400 mc
820-XLK-K-f*	12,400 to 18,000 mc

*fixed frequency in KMC/S

Note 1 — Frequency and power determined by Klystron used

LFE

INSTRUMENT DIVISION

LABORATORY FOR ELECTRONICS, INC.

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VARIABLE SCREW TUNERS
TERMINATIONS
HIGH POWER
LOW POWER
SLIDING
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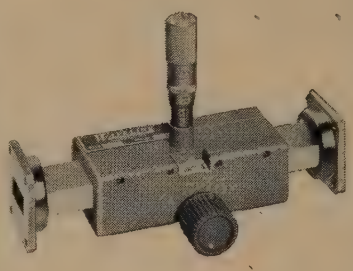
TRANSITIONS
SHORTING SWITCHES
ELBOWS and TWISTS



X-BAND WAVEGUIDE SWITCH

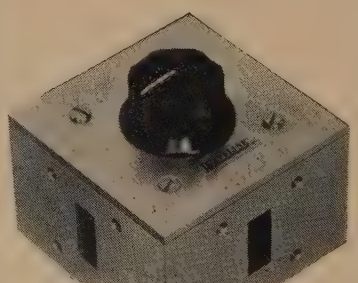
Model No. 678-E

This unit is a manually operated four port waveguide switch for use over the full range of 8.2 to 12.4 Kmc. This precision X-band has been designed for laboratory use or for systems application to make alternate connections between two waveguide inputs and two waveguide outputs.

Characteristics:

VSWR of less than 1.05
Isolation greater than 45 db.
Attenuation negligible

An "H" plane version of this switch is also available as Waveline Model No. 678-H.



WAVELINE INC.

CALDWELL, NEW JERSEY

Phone CApital 6-9100 TWX Caldwell, N. J. 703

Industry News

(*Continued from page 32*)

The microwave components organization of Airtron is responsible for the design and manufacture of the more sophisticated and complex microwave components such as ferrite devices, filters, mixer-duplexers, couplers, antenna components and other similar devices.

Roe formerly held sales and management posts with the Kellogg Division of International Telephone & Telegraph. Before joining Airtron he managed IT&T's activities in the 13 Southeastern states.

Roe is an electrical engineering graduate of Iowa State University and served with the Signal Corps and the Military Intelligence Division during World War II, at which time he was involved in military radar and counter-measures programs.

Airtron has its headquarters in Morris Plains, N.J., with additional plants in Linden, N.J., and a Pacific Coast facility in Los Angeles.

—*mwj*—

MOREY APPOINTED TO SALES POST AT WESTON

John G. Morey has joined Daystrom's Weston Instrument Division, Newark, N.J., as sales research and development coordinator, according to an announcement by W. H. Steinkamp, vice president of marketing.

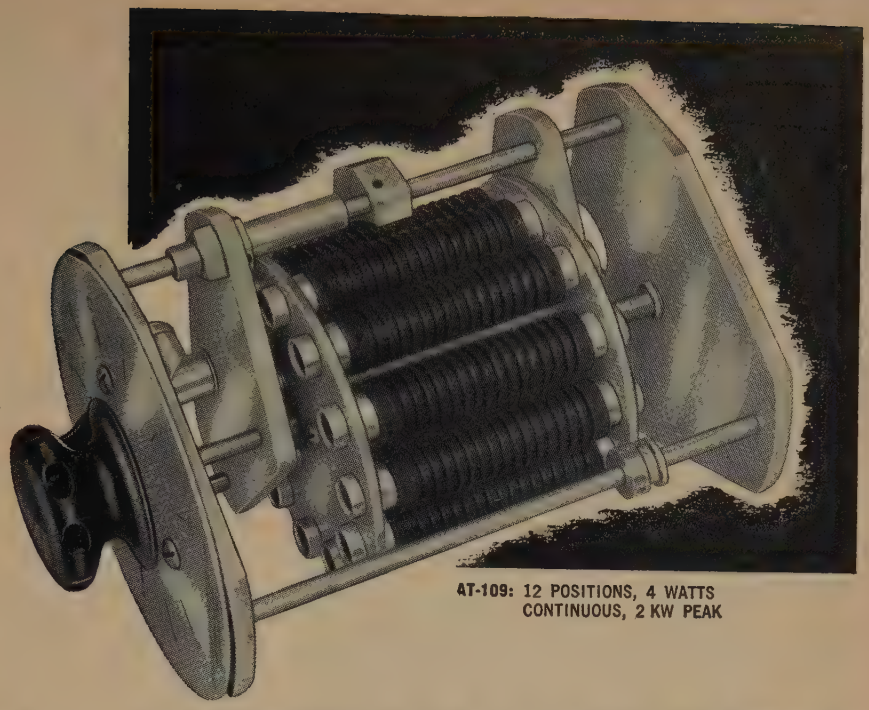
Morey was formerly Washington representative for the Ordnance Division of Clevite, Inc., Cleveland, O. He is a member of the National Security Industrial Association and the American Ordnance Association.

A physics major from Harvard in 1943, he served as liaison officer in the U.S. Navy Anti-Submarine Warfare program.

—*mwj*—

(*Continued on page 36*)

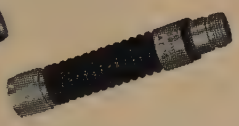
Accuracy
Reliability
Versatility



AT-109: 12 POSITIONS, 4 WATTS CONTINUOUS, 2 KW PEAK

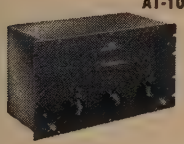
EMPIRE
COAXIAL ATTENUATORS

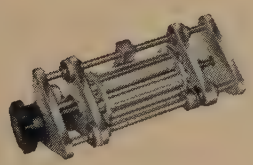
-50: 1 W CONT., 1 KW PEAK
-60: 2 W CONT., 2 KW PEAK



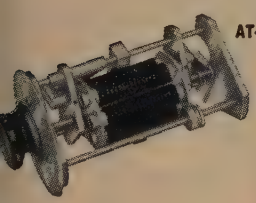
AT-75: 4 W CONT., 2 KW PEAK

AT-106: ATTENUATOR PANEL FOR VALUES UP TO 120 DB USING COMBINATIONS OF STEP ATTENUATORS.

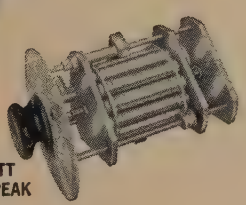




-103: 6 POSITIONS, 1 WATT CONTINUOUS, 1 KW PEAK



AT-108: 6 POSITIONS, 4 WATT CONTINUOUS, 2 KW PEAK



AT-104: 12 POSITIONS, 1 WATT CONTINUOUS, 1 KW PEAK

Rated up to 4 Watts

Empire attenuators have been designed and constructed for the reliable performance so essential to modern, complex systems. Their rugged construction . . . conservative power ratings for CW and pulse operation . . . and exclusive deposited carbon precision resistors . . . enable them to satisfy your microwave attenuation requirements.

Resistive coaxial networks shown here are intended for operation up to 4000 MC, a complete line of coaxial attenuators to 10,000 MC also available, and is described in our Catalog No. 604. Low VSWR and high accuracy are inherent features. Attenuation values up to 60 DB are obtained in individual pads, rated up to 4 watts continuous and 2 KW peak (AT-75) or as six and twelve position step attenuators (AT-108, AT-109). With two or three attenuators connected in series, values up to 120 DB can be obtained.

In many cases our engineering files contain a ready solution to your unusual coaxial attenuation problems.

For complete technical information, write for free Catalog No. 604.

edp

EMPIRE DEVICES
PRODUCTS CORPORATION
AMSTERDAM, NEW YORK **VICTOR 2-8400**

NOISE & FIELD INTENSITY METERS • CRYSTAL MIXERS • POWER DIVIDERS • DISTORTION ANALYZERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS

LEAK DETECTION to 10^{-13} CC/SEC (S.T.P.)

(Model 700B)

the Crosby-Teletronics ultra sensitive leak detector* is 1000 times more sensitive than any other mass spectrometer leak detector!

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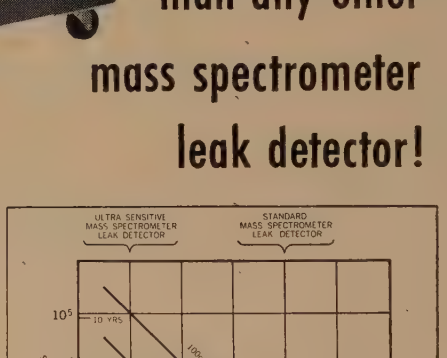
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** patent pending*

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Vacuum Research Division

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Industry News

(*Continued from page 34*)

NEW LABORATORY ESTABLISHED AT AIRTRON

Establishment of an Advanced Devic Laboratory at Airtron, a division of L ton Industries, Beverly Hills, Calif., h been announced by Harry J. Gray, pre ident and board chairman of Airtron.

The Advanced Devices Laboratory w established primarily to enable a sele group of specialists to devote full tir to research and development in the fie of microwave sub-systems, componen and materials. Specific fields of activi will be parametric amplifiers, ferri limiters using single crystal garnets a special application ferrite switches wi fast switching speeds.

The laboratory will be located at t Morris Plains, N.J., Airtron plant.

At the same time, William F. Boy vice president and general manager Airtron, announced the appointment Dr. Ernest Wantuch as director of t new laboratory. He has been in char of engineering of the Guideline activ in Morris Plains.

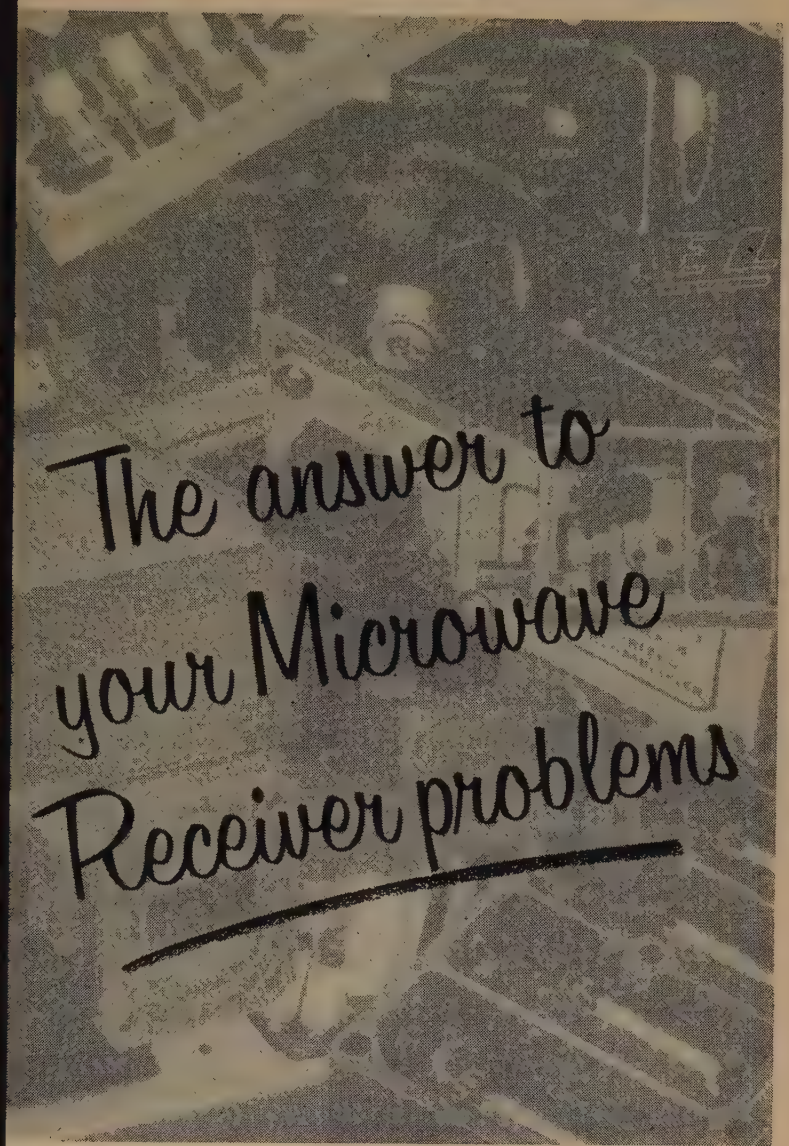
From 1956 to 1958, Dr. Wantuch w in charge of the Cambridge activity Airtron which was devoted to resear and development in the then relative new field of microwave ferrite devic This activity was combined with t Guideline division in Morris Plains 1958.

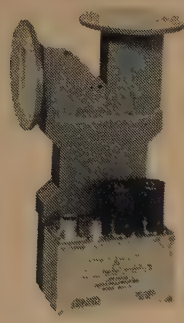
Dr. Wantuch received his PhD in ph sics from New York University in Ju 1950. From April 1951 to October 19 he was in charge of microwave develo ment at the Fairchild Guided Missile vision and from then until May 1956 w with the Missile Systems Division of Raytheon Manufacturing Co.

—*m w j*—

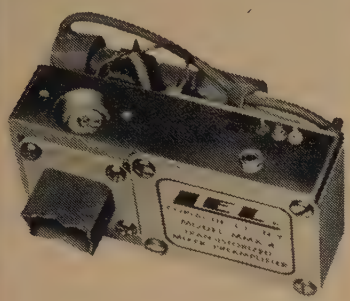
(*Continued on page 38*)

B½ db Min. Noise Fig. at X Band



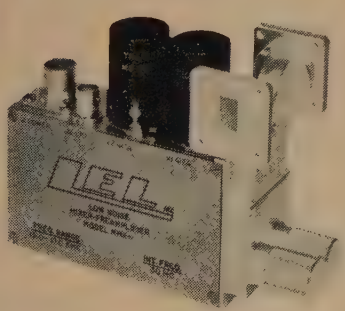


"C" Band



"X" Band
(Transistorized)

"S, L and C" Band
(Coaxial)



"K" Band

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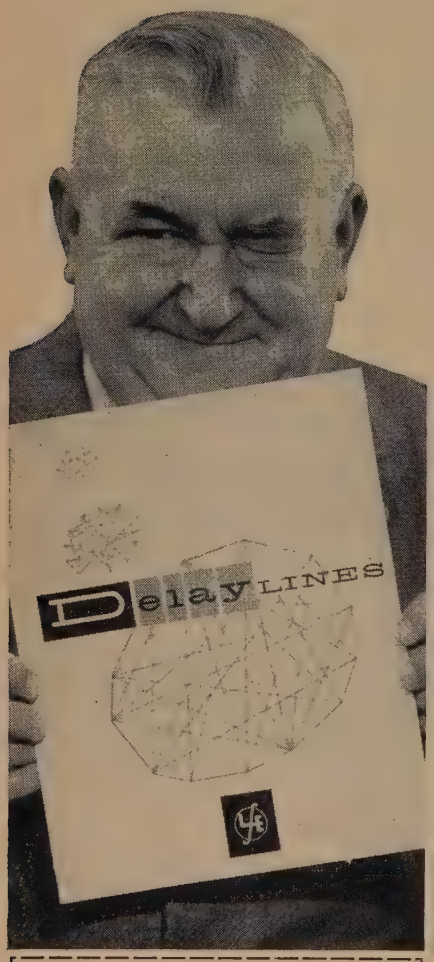

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Industry News

(*Continued from page 36*)

NEW COMPANY ORGANIZED

A new company serving the microwave industry in the area of special resistors, both microwave and microminiature, has been formed at Morristown, N.J. The new company is known as Film Resistors, Inc.

Heading the operation as president is Richard S. Ringer, formerly of Filmohm Corp. and Pyrofilm Resistor Co. Vice president is Savery Manfredonia. Acting as treasurer is Herbert Crover. Secretary is Kenneth Johnson, president of Jettron Products, Hanover, N.J.

The present building consists of 3000 square feet with an additional 10,000 feet available for expansion. Equipment includes the newest systems available for the deposition of carbon and metal films and also a modern machine shop. The company anticipates an employment force of 30 people. They are currently in production of special and microwave resistors, both metal and carbon film.

The company is located at 242 Ridgedale Ave., Morristown.

—*mwj*—

WHITLOCK NAMED TREASURER SPERRY GYROSCOPE CO.

Appointment of George F. Whitl to the executive position of treasu and secretary of the Sperry Gyrosc Co. was announced by Carl A. Friš president of the Great Neck, N.Y., e tronics company.

Mr. Whitlock, formerly secretary assistant treasurer for financial servi will be responsible to Edward M. Bro vice president for administration, for activities of the company's treasury vision.

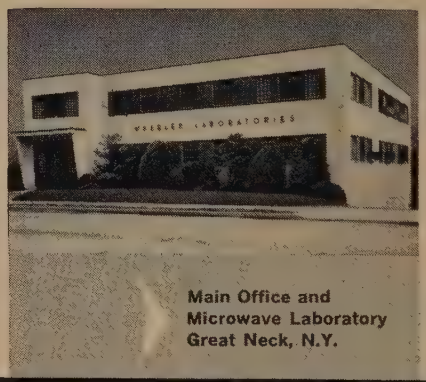
He joined Sperry in 1941, became gineering director for services at Sperry Research Laboratories in Gar City, and later director of services the Engineering Division at the c pany's main plant in Great Neck, N In 1952 he was appointed engineer manufacturing manager and in 1957 came secretary and assistant treasure

Prior to joining Sperry, Mr. Whitl was associated with Consolidated Edi Co. of New York, Koppers Construct Co., Pittsburgh, and the Brooklyn Un Gas Co.

Mr. Whitlock received a BS degree engineering at Brown University in 19 He is a resident of Garden City wh he has served as mayor and trustee the Village.

—*mwj*—

WL



Main Office and Microwave Laboratory Great Neck, N.Y.

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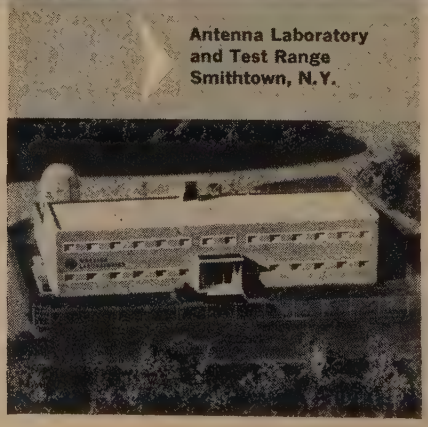

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Harold A. Wheeler and Engineering Staff

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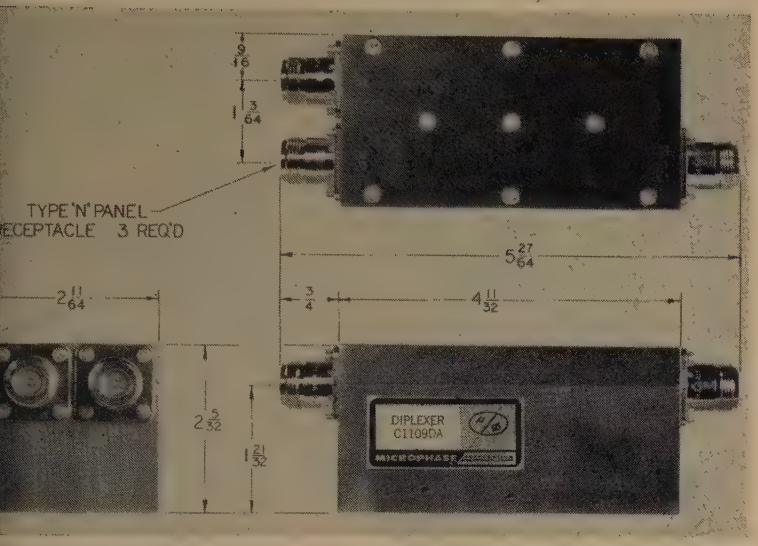

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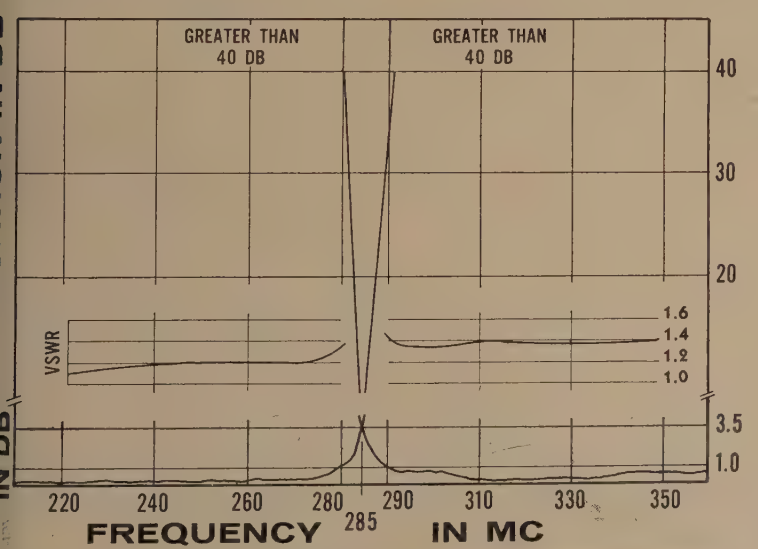

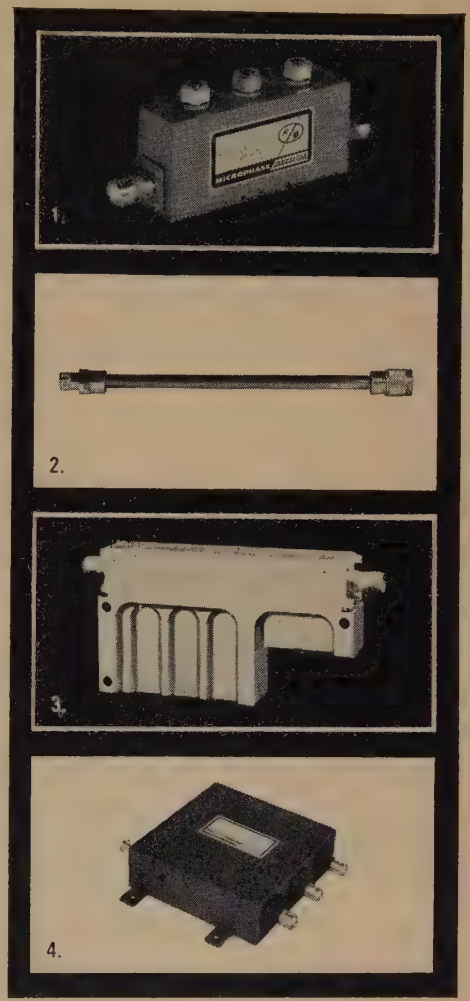

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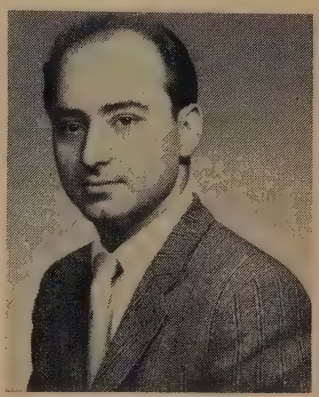
CONTRIBUTORS IN THIS ISSUE

DONALD M. BYCK was born June 17, 1931, in New York, N.Y. He received the BEE and MEE degrees in electrical engineering from Yale University in 1953 and 1955, respectively.

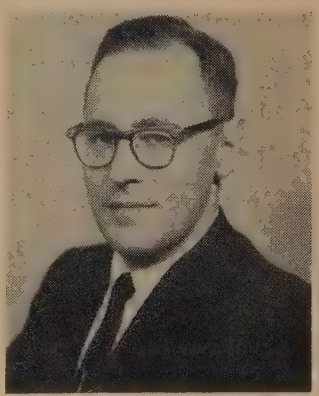
Since 1955 Mr. Byck has been affiliated with Electronic Associates, Inc., Long Branch, N.J. He was engaged in the design of electronic computing equipment prior to becoming a member of the staff at the company's Princeton Computation Center, Princeton, N.J. In 1957 he joined the Western subsidiary, EAI Computation Center, Los Angeles, Calif., where he was head of New Applications for Analog Computers.

Mr. Byck is presently on leave of absence at the Harvard Business School.



EPH D. CAPPUCCI was born May 11, 1931, in New York City. He received BEE and MEE degrees from City College of New York in 1956 and 1960, re-tively, following two years military service in the U.S. Army Signal Corps in 2-1953.

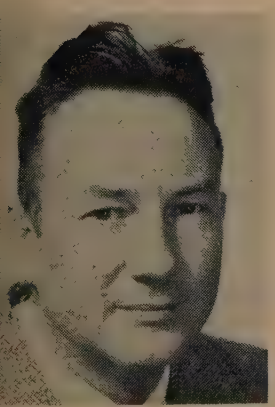
He was employed in 1956 and 1957 at the Materials Laboratory, New York al Shipyard, and at the ITT Laboratories at Nutley, N.J., from 1957 to 1959. Dur- this time he designed and developed various microwave components for both ile and countermeasure systems. Since early 1959, he has been with Merrimac earch and Development, Inc., as senior engineer, where his duties are to develop expand a line of novel commercial microwave components.



UNO O. WEINSCHEL attended the Technische Hochschule, Stuttgart, Germany; oklyn Polytechnic Institute, Columbia University and Georgetown University, shington, D.C., where he is presently working toward his doctorate in physics.

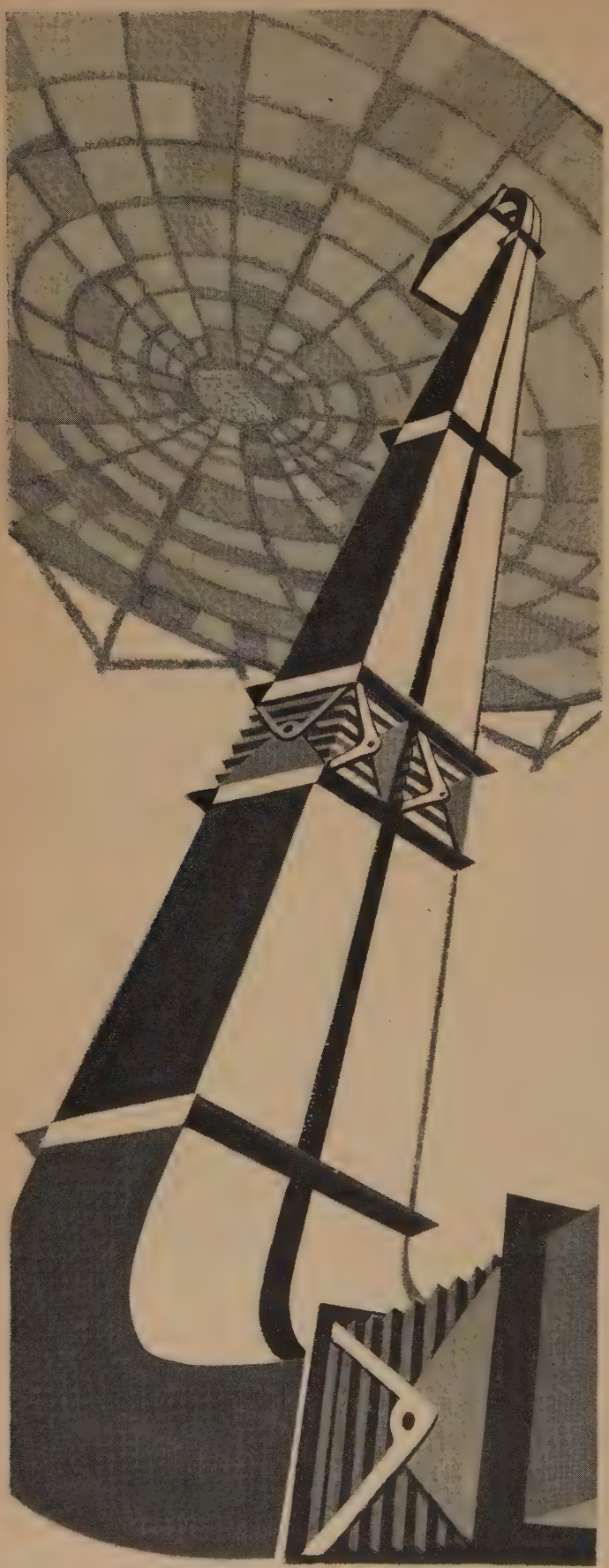
A registered professional engineer in the District of Columbia as well as in the e of Maryland, Mr. Weinschel was formerly chief engineer of the Industrial Instru- ts Co. and later consultant to the National Bureau of Standards. He founded Wein- l Engineering Co., Inc., Kensington, Md. in 1952 and is its President.

Mr. Weinschel is a senior member of the IRE, a member of the American In- te of Electrical Engineers, American Physical Society, American Association of Advancement of Science and the American Ordnance Association. He is currently rman of the Washington Chapter, Professional Group on Instrumentation, IRE, is a member of Commission I of URSI.



ALLEN NORRIS received his BS degree in 1941 from Stanford University and from 1942-46 did graduate studies in mathematics at the University of Chicago. From 1946-48 he was an instructor of optics and mathematics at Chicago College of Optometry and from 1948-51 he was mathematics consultant at Midway Consulting and Tutoring Service, Chicago, Ill. In 1951-52 he made wave propagation studies at Bell Aircraft Corp; in 1952-53 he worked on communications theory at the Radio and Television Division of Sylvania Electric Products, Inc., and from 1953-55 he worked on applications of new operator techniques to circuit-theoretic problems at Sylvania's Electronic Defense Laboratory.

Mr. Norris joined Varian Associates in April, 1955, where he is manager of Applied Mathematics. He is a member of the American Mathematical Society.



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nalog Simulation:

A NETWORK METHOD For SOLVING MICROWAVE PROBLEMS

ALLEN NORRIS
VARIAN ASSOCIATES
Palo Alto, California

DONALD M. BYCK
ELECTRONICS ASSOCIATES, INC.
Long Branch, New Jersey

roduction

Before the advent of present day computers, many engineering problems were not solved because of a lack of e or method. To some extent this is still true, but tronic computers are becoming more and more effective auxiliary analytical tools. The success of using analog nputers for microwave problems has been due primily to the computer characteristics which enable mathetical functions to be presented continuously rather than retely. For example, in bandwidth problems it is frently necessary to maintain the signal amplitude within cified limits over the *entire* band of interest, so a conuous representation is very convenient. Another imtant characteristic is the ability of the analog computer perform operations simultaneously rather than sequenly. This enables one to change a single parameter dur- the solution of an algebraic problem and immediately erve the result. When a microwave problem is "prop- stated," these two analog computer characteristics can used to reduce problem time significantly.

Proper statement" in this context means the judicious ice of equations that describe the problem. Microwave blems can usually be described by several mathematical dels, and the model chosen will determine whether or the results from the computer can be used directly or ther further data reduction is necessary. The choice mathematical models must be made by the design ineer because computer programmers will not normally acquainted with the physical aspects of the problem. make this choice, all the engineer needs to know are few general methods of solution employed by the puter and the form in which the results are obtained. s article will therefore discuss these points for five esentative mathematical models — ordinary differential ations, definite integrals, algebraic equations, transdental equations, and partial differential equations — g five microwave problems as examples. The examples sen are:

(1) Electrostatic Focusing — ordinary differential equations
(2) Frequency Analysis by Fourier Transformation — definite integrals
(3) Broadbanding of Klystron Amplifiers — algebraic equations
(4) Propagation Characteristics of an Inhomogeneous Waveguide — transcendental equations
(5) Resonance Characteristics of Microwave Cavities — partial differential equations

Description of a General Analog Computer

Analog computation is a network method of analysis with circuits representing equations and voltages in these circuits representing the mathematical variables. The technique of programming consists of establishing the given mathematical relationships of a problem with the computer circuits. This is carried out physically by wiring a patchboard which is then inserted into the computer. Numerical values of constants and parameters are assigned by adjusting potentiometer settings. To obtain a solution, signal voltages representing the known variables are applied to the computer circuit. The voltages representing the unknown variables are recorded by x-y plotters which display continuous curves of one variable plotted against another. In addition, strip chart recorders which plot up to eight variables simultaneously may be used. This analog procedure is similar to the well known engineering technique of simulating physical systems or mathematical equations with networks of passive elements. However, the computer components are electronic and electromechanical devices which perform addition, subtraction, multiplication, division, function generation, and integration.

A typical present day analog computer contains groups of these basic components assembled in electronic racks and wired to a central operating console. A section of the console of a computer (Electronic Associates PACE

231-R) is shown in Figure 1. The inputs and outputs of all components, as well as the inputs of the recorders, are individually terminated at a matrix of spring contacts centered behind the holes in the patchboard. Interconnections are made by inserting "patchcords" and "bottle-plugs" into the front of the patchboard so that a completely wired problem can be removed from the computer and stored. Adjacent to the patchboard are a digital voltmeter, several computing components — including a row of coefficient potentiometers, the control panel containing operating switches, a meter for monitoring power supplies, and a pushbutton system which enables any of the computer voltages and potentiometer settings to be selected for readout on the digital voltmeter and its associated printer. It can be seen that the analog computer is, in principle, a collection of mathematical components which can be selected as needed for a particular problem.

Electrostatic Focusing

After the problem has been defined, the first step in computer programming is to draw a flow diagram which specifies the interconnections for the computer components. Such a diagram for an electron trajectory in an electrostatic field is shown in Figure 2.[a] After the computer has been wired according to this diagram, values are selected for an electron's initial velocity and position by adjusting the four initial value potentiometers. The computer is then turned on, and the trajectory is plotted on an x-y recorder.

The computer circuit may be drawn from the equations by the following procedure:

(1) In starting the diagram, x and y are *assumed* to be known quantities at the inputs to the function generator.

(2) The components required to form $\ddot{x}$ and $\ddot{y}$ are then drawn.

(3) Successive integrators are added until x and y are reproduced as outputs.

(4) To complete the diagram, the outputs are fed back to the points on the diagram at which x and y have been assumed.

[a] Details such as numerical scale factors and patchboard identification numbers have been omitted. The "reference" inputs are accurate sources of + or — 1 volt.

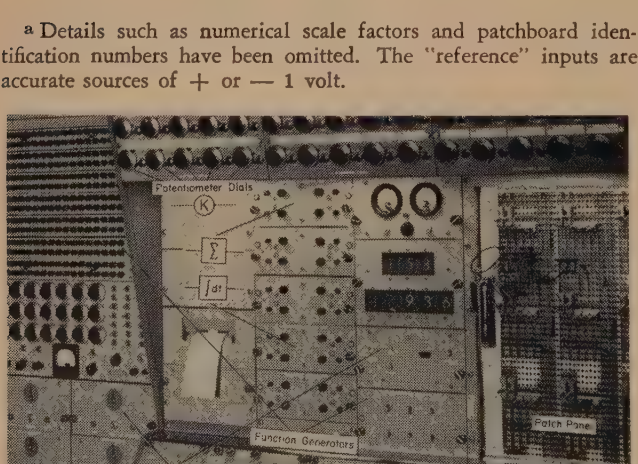
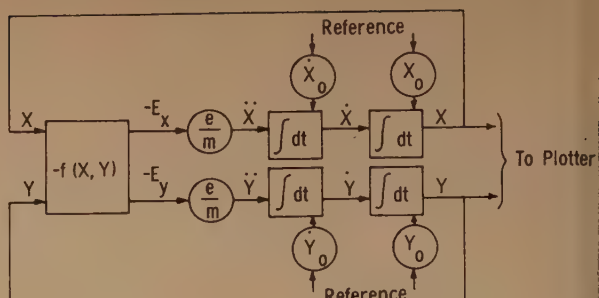


Figure 1 — Pace 231-R.



$$\ddot{X} = \frac{-e}{m} E_x(X, Y)$$

$$\ddot{Y} = \frac{-e}{m} E_y(X, Y)$$

Figure 2

This procedure is merely a convenient artifice for drawi a "feedback" flow diagram representing the traject equations. The general procedure, sometimes called "i method of successive integrations," may be extended any set of differential equations by rearranging each eq tion so that the highest order derivative term is transpos to the left of the equal sign. In many problems there w be several terms on the right of the equal sign rather th the single term which appears in the trajectory equatio For this reason, the integrators have been designed accommodate normally up to seven inputs, with provis for adding more if necessary.

For a specific example of how the field functi $E_x(x,y)$ and $E_y(x,y)$ may be treated, consider a slalo focused TWT. The electrode structure and result equipotential lines are depicted in Figure 3.[b] The dc el tric field equations for this computation have been sho to be: [1]

$$E_x(x,y) = \frac{V_0\pi}{a} \frac{\sin X}{\cosh Y - \cos X}$$

$$E_y(x,y) = \frac{V_0\pi}{a} \frac{\sinh Y}{\cosh Y - \cos X}$$

Of course it would be possible to set up an electrol tank model, or use computer function generators to proximate these functions. However, since the functi have been described analytically, it is possible to us more accurate method which requires no setup time p

[b] Under proper injection conditions, an electron will fol the crossover equipotential lines which wind about the electrodes.

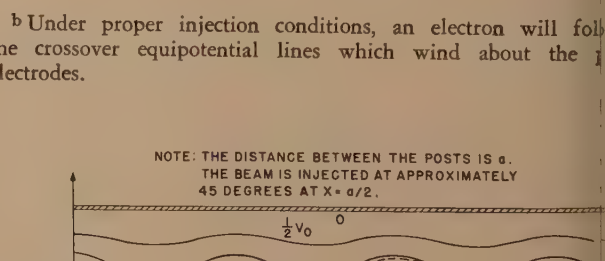
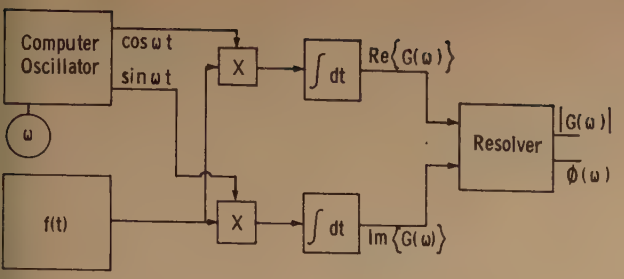


Figure 3



$$\mathrm{Re}G(\omega) = \int_0^{\infty} f(t)\cos\omega t\, dt$$

$$\mathrm{Im}G(\omega) = \int_0^{\infty} f(t)\sin\omega t\, dt$$

Figure 4

computations. Differential equations which have sin, os, sinh, and cosh as their solutions can be written. For xample, to generate sinh y and cosh y let:

$$u = \sinh y$$

nd

$$v = \cosh y$$

nce

$$\dot{u} = \dot{y}\cosh y$$

nd

$$\dot{v} = \dot{y}\sinh y$$

nen

$$\dot{u} = \dot{y}\, v \qquad (3)$$

nd

$$\dot{v} = \dot{y}\, u \qquad (4)$$

hich are the desired equations.[c]

The flow diagram for these equations may be drawn y the method of successive integrations which was out- ned earlier. The required components are multipliers to rm the products $\dot{y}v$ and $\dot{y}u$ and then integrators to ob- in u and v. Sin x and cos x are treated similarly. When ey are combined with sinh y and cosh y by the appro- iate computer components, as specified by Equations 1) and (2), a resultant circuit is obtained for replacing e block labeled f(x,y) in Figure 2.[d]

The electron trajectories are obtained by plotting x vs with a two-coordinate plotter. An example of an actual lution under r-f conditions is shown as the dotted line Figure 3. The r-f conditions are accounted for by adding rms to Equations (1) and (2).

It would, of course, be possible to record any of the variables x, y, $\dot{x}$, and $\dot{y}$ vs time, by using a strip chart recorder in addition to the x-y plotter.

Programming and patching for Equations (1) through (4) would normally require from 2 to 4 hours, depending on the experience of the programmer. The computing time per trajectory would be 30 seconds to 1 minute depending upon the time scale selected for the problem.

[c] The operation of the computer integrators is based on the ne charging of a capacitor. Thus, *for all differential equation lutions* the computer analog of the independent variable is ne. It is for this reason that the newly defined variables, u and are differentiated with respect to time rather than with respect y.

[d] Due to the differentiation process used in generating the func- n f(x, y) the inputs to this circuit will be $\dot{x}$ and $\dot{y}$ rather an x and y. This may be observed by drawing the flow diagram, ting that $\dot{x}$ terms will occur in the equations for cos x and sinh in the same manner that the $\dot{y}$ terms occur in Equations (3) d (4).

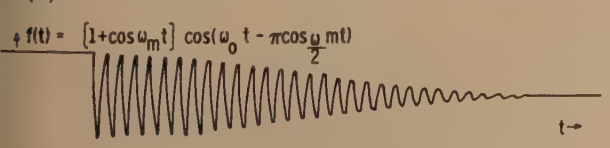


Figure 5

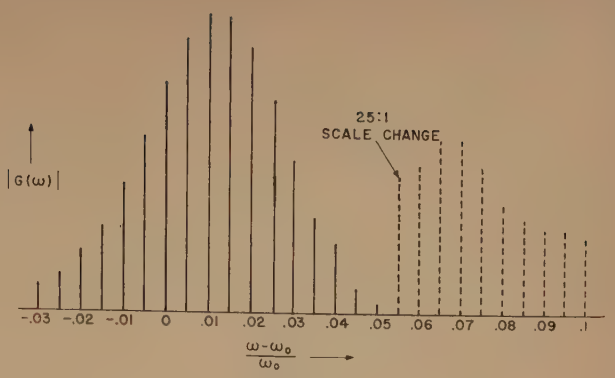


Figure 6

Frequency Analysis by Fourier Transformation

The analog method of solving definite integrals is quite straight-forward, the major problem being to generate suitable integrands. This is done either by using function generators or by applying the differential equation method described above. Applications have included the calculation of Fourier transforms to obtain frequency spectra of microwave pulses and to obtain radiation patterns for antenna field distributions.[2]

A flow diagram for a Fourier transformation is shown in Figure 4. The computer oscillator consists of circuits which solve the differential equations of simple harmonic motion. The output block is a resolver designed to compute the magnitude of a vector from its components.

The output of a pulsed klystron amplifier which has been analyzed by this circuit is shown in Figure 5, and the amplitude spectrum for the pulse is shown in Figure 6. Each point was obtained by integrating the function for discrete values of the parameter ω. The phase function is not shown, but it is also obtainable from the output of the resolver.

Because of the very high ratio ω_o/ω_m for which this problem was solved, continuous representation of the pulse was important. The estimated overall accuracy for the problem was 0.1 percent, utilizing computing times from 1 to 2 minutes per point on the spectrum.

Broadband of Klystron Amplifiers

When a microwave device is described in terms of sinusoidal steady-state operation, an impedance model of the device is obtained. This algebraic model can in turn be used to study bandwidth characteristics. An interesting feature of such algebraic calculations is that the computer model of the microwave network simulates a laboratory setup driven by a swept frequency source.

The gain-bandwidth response of a multicavity klystron amplifier is described by a large number of algebraic calculations, consisting of product and sum combinations of the responses for the individual cavities. For convenience, we shall look at the equation for the first cavity only.

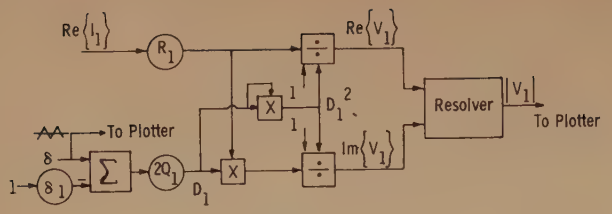


Figure 7

$$V_1 = \frac{I_1 R_1}{1 - j2Q_1(\delta - \delta_1)} \qquad (5)$$

where

I_1 = complex excitation current at the first cavity
V_1 = complex voltage developed across the first cavity
R_1 = resistance component of the shunt impedance measured at the first cavity gap
Q_1 = overall Q of the first cavity
ω_o = center frequency of the amplifier
ω_1 = resonance of the first cavity
$\delta = (w - w_0)/w_0$ = normalized frequency deviation
$\delta_1 = (w_1 - w_0)/w_0$ = normalized detuning of the first cavity

Since the variables are complex, the equations must first be rewritten in terms of real and imaginary parts. This separation leads to:

$$\text{Re } (V_1) = \frac{\text{Re } (V_1) + D_1 \text{ Im } (I_1 R_1)}{1 + D_1^2} \qquad (6)$$

$$\text{Im } (V_1) = \frac{\text{Im } (I_1 R_1) - D_1 \text{ Re } (I_1 R_1)}{1 + D_1^2}$$

D_1 being equal $2Q_1 (\delta - \delta_1)$.

The flow diagram for this cavity is shown in Figure 7. Only the real part of I_1 appears, since the subscript denotes the first cavity and I_1 has been chosen as the reference phasor. The operation of this circuit may be explained as follows. The physical input to the circuit is a constant voltage representing the amplitude of the constant current input of the actual klystron. The remainder of the circuit, excepting the resolver, is essentially a dc amplifier whose gain function is equivalent to the impedance vs frequency function of the cavity. This gain function is controlled by the computer voltage representing δ. Hence, by cyclically varying this voltage, the swept frequency simulation is obtained. The resolver may be viewed as a mathematical measuring instrument which combines the voltage components necessitated by the calculation procedure. Th result is the actual amplitude of the cavity output voltag Bandwidth characteristics are optimized by adjusting th parameters R_1, Q_1, and δ_1 while observing plots of th output. The results for a six-cavity klystron are show in Figure 8.

In a six-cavity amplifier there are about 30 parameter which may be adjusted (including gap coupling coeffi cients, drift space lengths, and beam constants). Such a amplifier can normally be optimized in 4 to 12 hour This depends on the freedom with which the designe may select parameter values. Hand calculations for small number of representative combinations of thes parameters would require several weeks. One of the ad vantages of the analog method is that the designer ca operate the computer and eliminate large areas of searc by utilizing his experience with similar tubes in th laboratory.

Another problem which has been solved by this metho is that of matching a load to a waveguide transmissio line, utilizing multi-element matching to obtain broa bandwidth characteristics. In this problem the combina tion of element impedances and spacings which giv the optimum bandwidth characteristics are determine Of particular importance is the fact that measured loa frequency functions can be programmed directly into th computer. The measured function is approximated by 2 linear segments. The ordinates and abscissas which d fine these segments are set into computer function ge erators by adjusting potentiometer settings. The functio generators then provide linear interpolation to yield continuous representation for the computer. Several fun tion generators can be combined if more than 20 se ments are required for adequate representation. Thes function generators use adjustable biased diodes to contr the gain of a dc amplifier according to the amplitude the input to the amplifier.[3] An alternative type of functio generator utilizes an electromechanical curve follower obtain a voltage representation directly from a graph the desired function.

Waveguides: Propagation Characteristics

When discontinuities occur in waveguides or whe materials are introduced to form several dielectric regio propagation characteristics can be specified mathematicall by matching field solutions at the boundaries between th media. This field matching technique results in tran cendental equations which must be solved to determi propagation characteristics as a function of the drivi frequency and the relative dimensions and properties the materials. The solution of these equations general calls for a trial and error method which is unduly tim

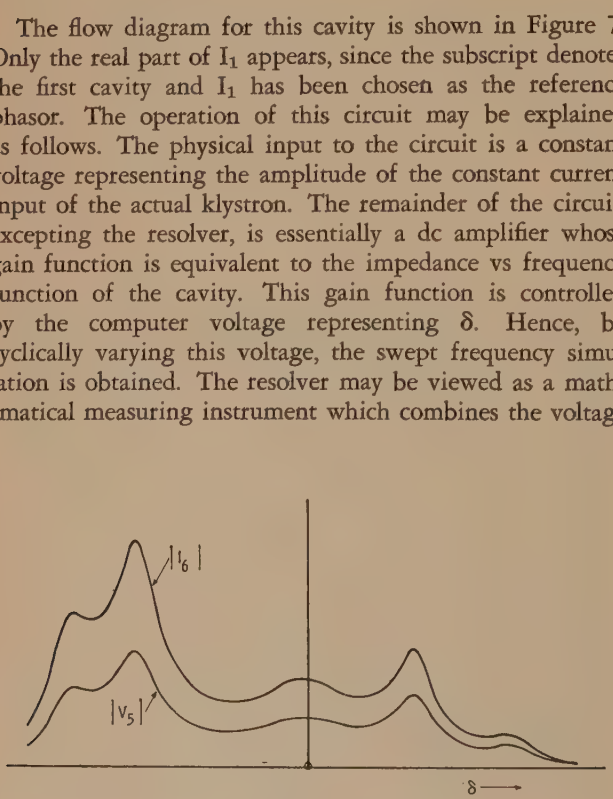


Figure 8

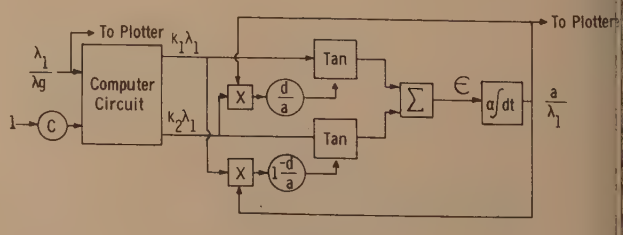


Figure 9

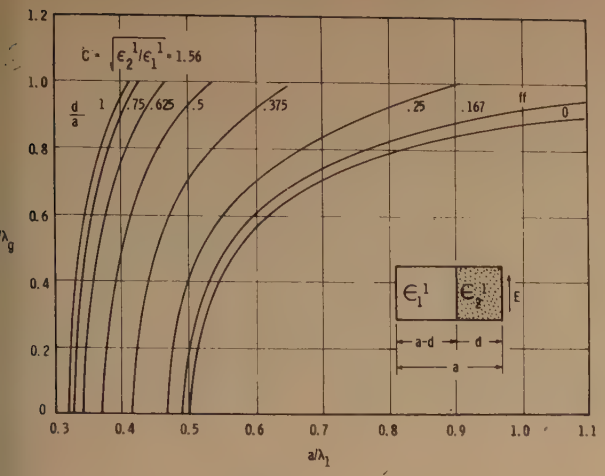


Figure 10

suming. The analog computer, on the other hand, ers a convenient means for obtaining numerical results the form of continuous curves.[3] As an example, consider uation (7) which describes the propagation character- cs in a waveguide partially filled with two dielectrics:

$$k_1 \tan k_2 d = -k_2 \tan k_1 (a-d) \qquad (7)$$

ere

$$k_1 = \frac{2\pi}{\lambda_1}\sqrt{1-\left(\frac{\lambda_1}{\lambda_g}\right)^2}$$

$$k_2 = 2\sqrt{C^2-\left(\frac{\lambda_1}{\lambda_g}\right)^2}$$

$$C^2 = \frac{\epsilon^1{}_2}{\epsilon^1{}_1}$$

ere $\epsilon_1{}^1$ and $\epsilon_2{}^1$ denote dielectric constants in the media d λ_g is the waveguide wavelength along the longitudinal s. The computer is programmed to obtain a solution the relationship between the normalized variables λ_1 and λ_1/λ_g. Prior to this, one defines an error func- n $\epsilon = \epsilon(t)$ as

$$\epsilon \equiv \frac{1}{\alpha}\left[\frac{d}{dt}\left(\frac{a}{\lambda_1}\right)\right] \equiv \lambda_1\left[k_1 \tan k_2 d - k_2 \tan k_1 (a-d)\right] = k_1\lambda_1 \tan\left[k_2\lambda_1\left(\frac{a}{\lambda_1}\right)\frac{d}{a}\right] - k_2\lambda_1 \tan\left[k_1\lambda_1\frac{a}{\lambda_1}\left(1-\frac{d}{a}\right)\right] \qquad (8)$$

e method of solution of Equation (7) is to solve Equa- n (8) for $\frac{a}{\lambda_1}$ where the proportionality factor α d the parameter λ_1 can be varied to produce a zero error nal $\epsilon = 0$ (see Figure 9—the initial error existing when computer is turned on is integrated, causing the value (a/λ_1) to change in such a way that the error is driven zero). Thus the circuit illustrated in Figure 9 thus a continuous error-nulling device. A plot of the ults for this problem is shown in Figure 10.

An extension of this method is used in solving simul- eous algebraic equations. Since the number of equa- ns must equal the number of unknowns, each of the or functions may be assigned to one of the unknown

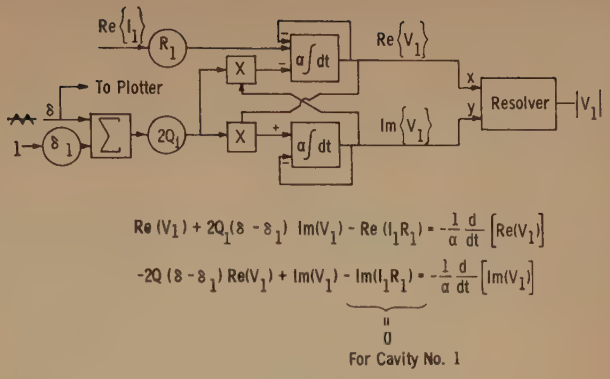


Figure 11

quantities. The computer circuit then consists of several error-nulling devices which work simultaneously. This is illustrated in the flow diagram, Figure 11.[e] The equations used in this diagram represent a klystron cavity and are alternative to those given in the section on klystron amplifiers. They are obtained from Equation (5) by cross multiplying and separating real and imaginary terms. Ordinarily one is interested in solving algebraic systems containing a larger number of such equations.

Microwave Cavities: A Boundary Value Problem

The purpose of this discussion is to illustrate the analog computer technique in solving a simple type of boundary value problem occuring in microwave theory. The example is an air filled rectangular cavity. The field in this cavity is given by:

$$\frac{\partial^2 E_y}{\partial x^2} + \frac{\partial^2 E_y}{\partial z^2} + \omega_0^2 E_y = 0 \qquad (9)$$

The method of solution is to replace the partial derivatives with respect to x and z by finite differences. To do this, a number of discrete points are selected in the cavity. (See Figure 12). The finite difference expressions for the nmth point is: [4]

[e] The derivative terms represent no change in method (if $X = \alpha\int\epsilon dt$, $\dot{X} = \alpha\epsilon$), but they do permit use of the successive integrations procedure described in the section on electrostatic focusing.

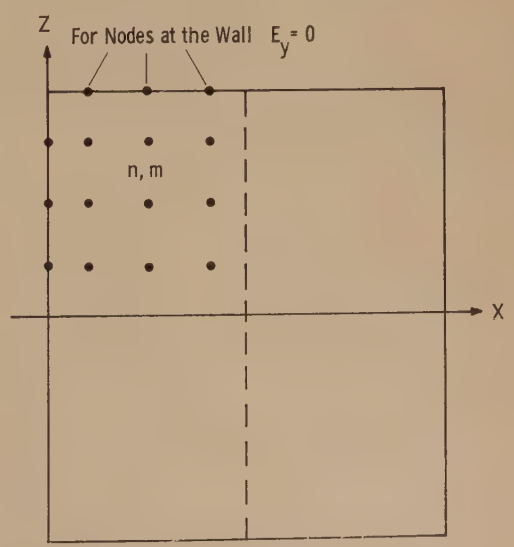


Figure 12

$$\left.\frac{\partial^2 E_y}{\partial x^2}\right]_{nm} = \frac{E_{yn,\,m-1} - 2\,E_{ynm} + E_{yn,\,m+1}}{2\triangle x^2} \qquad (10)$$

$$\left.\frac{\partial^2 E_y}{\partial x^2}\right]_{nm} = \frac{E_{yn-1,\,m} - 2\,E_{ynm} + E_{yn+1,\,m}}{2\triangle z^2}$$

Substituting these expressions in (10) yields

$$\frac{E_{yn,\,m-1} - 2\,E_{ynm} + E_{yn,\,m+1}}{2\triangle x^2} + \frac{E_{yn-1,\,m} - 2\,E_{ynm} + E_{yn+1,\,m}}{2\triangle z^2} + \omega_o^2\,E_{ynm} = \frac{1}{\alpha}\frac{\delta}{\delta}(E_{ynm}) \qquad (11)$$

where the derivative term has been inserted as an error function. This term is an artifice to enable one to solve the simultaneous algebraic equations in the manner described above. The system of equations given by (11) is solved by adjusting potentiometers representing the eigenvalue parameter ω_o^2 until the errors are nulled. The computer circuit for this problem has a stable equilibrium only for the first eigenvalue. At any other point, either the balancing circuit is unstable or the solution is the trivial one of no fields. The field solution at the discrete points of the cavity given by Equation (11) and the value of ω_o are printed out by a digital printer.

This method is particularly useful for boundary value problems which cannot be solved analytically because of difficult geometrics. An extension of this method has led to a solution for the case of a ferrite-loaded rectangular cavity with the ferrite slabs adjacent to the cavity walls.

Summary

This paper has presented some of the characteristic features of solving microwave problems with an analog computer. It is certainly of primary importance that the mathematical model chosen be such that the results are obtained in a convenient form. This ordinarily means that the mathematics describing the physical situations of interest be set up with a computer solution in mind.

Secondly, it is difficult to overstate the importance of analog machines as laboratory tools. The variety of examples discussed above is sufficient testimony to the adaptability of the computer to problems of widely different mathematical nature. Moreover, in selecting the simulation techniques for solving the problems, the advantage of continuous representation of mathematical functions may be employed to study response curves throughout the domain of interest. Such an advantage is e tremely useful in studying the implications of new mathi matical models. In addition, the analog computer pro erty of performing its operations simultaneously rath than sequentially is of particular importance to the desi engineer. The analog computer can simulate the equi ment being designed and the variation of a single par meter frequently yields satisfactory design information

These two roles, the one of yielding numerical solutio to theoretical equations and the other of assuming t role of an experimental design instrument, are compl mentary and, if the mathematical model is in the prop form, analog computation applies equally well to theo and application.

Footnotes

1. Willis Yocum *et al,* "Stability of an Electron Beam on Slalom Orbit," *Journal of Applied Physics,* Volume 29, Marc 1958, pp. 583-587.

2. A. I. Rubin, J. P. Landauer, and H. Q. Totten, "Far Fie Antenna Pattern Calculations by Means of a General Purpo Analog Computer," *National Electronics Conference,* Octob 1959.

3. For a more complete discussion of this application of anal simulation refer to Donald M. Byck and Allen Norris, "C the Solution of Some Microwave Problems by an Analog Co puter," *1958 IRE WESCON Convention Record,* Volume Part 1, pp. 70-85.

4. A discussion of general finite difference techniques wh are applicable to the solution of two-dimensional second or boundary value problems is given by R. H. Macneal, "A Asymmetrical Finite Difference Network," *Quarterly of A plied Mathematics,* Volume 11, October, 1953, pp. 295-31

References

For the microwave engineer who is interested in anal computers and their application, one or more of the fo lowing books might be useful:

(1) Johnson, Clarence L., *Analog Computer Techniques,* M Graw-Hill Book Company, 1956.

(2) Korn, Granino A. and Theresa M. Korn, *Electronic A alog Computers,* 2nd Edition, McGraw-Hill Book Compan 1956.

The reader should note the excellent bibliography in th text on pages 429-440.

(3) Soroka, Walter W., *Analog Methods in Computation a Simulation,* McGraw-Hill Book Company, 1954.

Also, there are numerous periodicals directly or indirec concerned with our subject. Of particular significance i *Transactions of the Professional Group on Electronic Co puters,* Institute of Radio Engineers, New York.

ZERO—LOSS WIDEBAND COAXIAL LINE VARIABLE ATTENUATORS*

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ntroduction

Components such as variable attenuators have not een generally available commercially in coaxial line ecause of the structural difficulties inherent in the use f this line. These components can, however, be readily bricated for use in coaxial line systems by employing odified coaxial structures. Typical of such structures re the "plate" and "ridge" coaxial lines described be- w. Several of the attenuators which have been con- ructed in these lines will be described in this paper.

Coaxial lines possess two highly desirable character- tics: (a) wideband single mode operation, in which ne (dominant) mode has no low frequency cut-off alue, and (b) the line cross-section can be made arbi- arily small, in view of property (a). The popularity f coaxial lines has been limited, however, because of ne structural difficulties encountered in designing com- onents in the line.

Rectangular waveguide is simple structurally, and the brication of components in it has met with distinct ccess. It suffers, however, from its bandwidth limi- tion and its large size at the lower frequencies.

In the past few years, new guiding structures have been oposed which combine small cross-sectional size with ideband characteristics. Among these are ridge wave- uide, microstrip line, and symmetrical strip line. Ridge aveguide is essentially an extension of rectangular wave- uide in which the bandwidth is greatly increased by pacitively loading the center region of rectangular wave- uide, with the prime effect of lowering the dominant ode cut-off frequency. Although recent designs permit ndwidths of 3 or 4 to 1, these can be achieved only at e expense of small and accurately held gap spacings.

In contrast to ridge waveguide, which is a modification of rectangular waveguide, microstrip (consisting of a strip over a single groundplane) and symmetrical strip line (in which the strip is located symmetrically between two groundplanes) are modifications of the two wire line and the circular coaxial line, respectively. These lines are shown in Figure 1. Both of these lines have dominant modes with zero cut-off frequencies, so that they possess the wideband characteristics of coaxial line. Due to their simple structure, they permit many components to be connected together in a compact fashion. However, microstrip is an open line in which some radiation occurs at every junction, thereby limiting the usefulness of the line in the fabrication of a system. Symmetrical strip line is also an open line but to a much smaller extent. Junctions in symmetrical strip line are non-radiating (purely reactive) only if strict symmetry is maintained at the junction

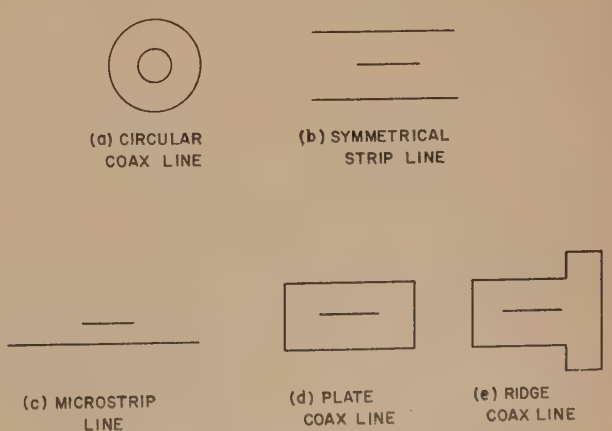


Figure 1 — Types of transmission lines.

*Patent Pending.

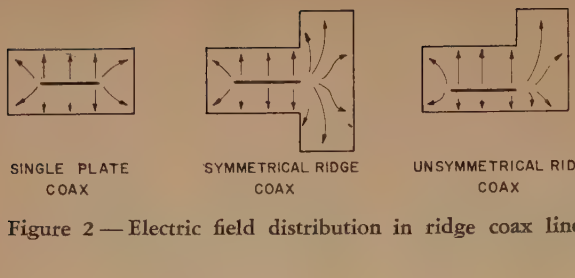


Figure 2 — Electric field distribution in ridge coax lines.

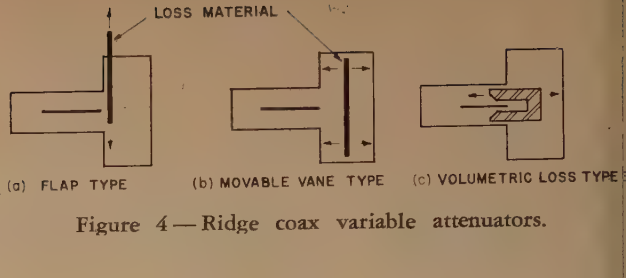


Figure 4 — Ridge coax variable attenuators.

between the upper and lower groundplanes, or if the junction is approximately boxed in. The line may be regarded as possessing two fundamental modes — one, the strip line itself, and the other the parallel plate mode which will radiate power away from the strip region; as long as strict symmetry is maintained, this second mode is not excited. Despite the above mentioned difficulty, the structural conveniences provided by the strip type of line are in no sense to be minimized.

The purpose of this paper is to indicate how one can salvage the existing engineering developments of coaxial line and overcome the structural disadvantages associated with components by constructing the latter in modified coaxial form. The modified structures employed are essentially distortions of the basic circular coaxial line but do not constitute as radical a change as symmetrical strip line. They are intermediary modifications which serve not to replace ordinary coaxial line but rather to extend its usefulness.

Typical modified coaxial structures which have been found useful in the design of components are shown in Figure 1. They are designated as *plate and ridge coaxial lines* to distinguish them from the various strip lines discussed in the literature. They differ from the strip lines in that they are completely closed structures; they cannot radiate and they possess only a single dominant mode. (It may be noted that the outer conductor of the ridge coax line of Figure 1 is actually half of the usual ridge guide configuration). In addition to variable attenuators, components such as octave-bandwidth magic tees and slide-screw tuners have been developed in these lines, but only the attenuators are described in this paper.

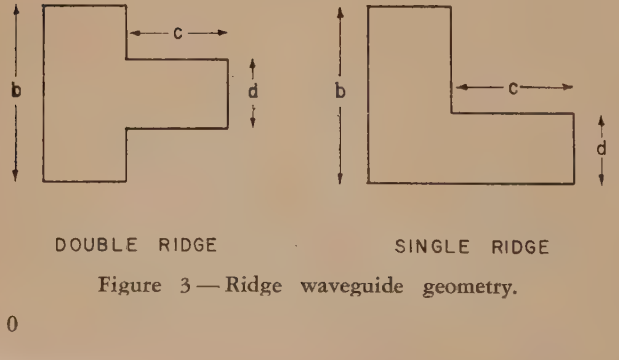


Figure 3 — Ridge waveguide geometry.

Ridge Coax Variable Attenuators

While a variable attenuator can be fashioned in th single plate coax line of Figure 1 (d), a much bette one may be obtained by use of the ridge coax line o Figure 1 (e). The ridging serves two functions: (a) t create large concentrations of field at the ridge corner in addition to that already present at the center conducto edge, and (b) to flare out the lines of electric field in th neighborhood of the ridge so as to create a sizeable regio in which the electric field lines are parallel. The first o these functions permits a high maximum value of atten uation when a resistance card is placed parallel and nex to the vertical sides of the ridge. The second function per mits a smooth control over the attenuation value as th resistance card is moved away from the above-mentione position.

Figure 2 illustrates the disposition of the electric fiel lines in the various plate coax structures, and bears ou the remarks of the paragraph above. Two ridge coa structures are shown: a symmetrical ridge line and an un symmetrical ridge line. Although both are satisfactor structures, the former line is to be preferred because i permits a somewhat greater maximum attenuation valu and because its junction with conventional coax line i easier to match over a wide band.

A variable attenuator can be fashioned in symmetri strip line by employing either loss cards or volumetri loss material, provided that they are introduced in sym metric fashion. However, the symmetric strip line an the ridge coax line differ essentially in two ways: (1) th presence of the ridge which fringes out the fields, an (2) the closed nature of the latter line. The consequence of feature (1) is that the lossy card or vane may b used to obtain large attenuations in a smoothly controlle manner. Consequences of feature (2) are: (a) the pres ence of the side wall insures the condition of low initia loss when the thin vane contacts the wall. As a resul smaller transverse dimensions are possible. (b) The co axial ridge attenuator may be operated in unsymmetric fashion. (c) Spurious radiation effects are avoided.

The dominant mode in the ridge coax line is evidentl a TEM mode. As the frequency is increased, howeve higher modes will be capable of propagating. The fir two of these are the first higher mode in the ridge coaxi

igure 5 — Variable attenuator of the moveable vane type (Model A-10).

ne, and the lowest ridge waveguide mode, which is un-tached to the inner conductor. The cut-off wavelength f the former of these higher modes may be estimated, as n conventional coaxial line, as the average periphery be-ween the inner and the outer conductors (ignoring the dditional fringing region to a large extent). The cut-off avelength λ_c of the lowest mode in the ridge waveguide, hich is not of conventional shape, is given to a high egree of approximation by the transcendental relation:

$$\frac{2b}{\lambda_c} \ln \csc \frac{\pi d}{2b} = \cot \frac{2\pi a}{\lambda_c} + \frac{b}{d} \cot \frac{2\pi c}{\lambda_c} \qquad (1)$$

or the symmetrical case, and

$$\frac{4b}{\lambda_c} \ln \csc \frac{\pi d}{2b} = \cot \frac{2\pi a}{\lambda_c} + \frac{b}{d} \cot \frac{2\pi c}{\lambda_c} \qquad (2)$$

or the unsymmetrical case, where the dimensions in-olved are indicated in Figure 3. As mentioned earlier, hese cross-sections are half of the usual ridge waveguide ross-sections, so that the above fundamental mode cut-off avelengths are the same as those for the TE_{20} mode in he usual ridge waveguides. Since the cross-section di-ensions of the ridge coax attenuators must be kept fficiently small in order to maintain the ridge waveguide ode below cut off, the cross-section dimensions of the dge coax attenuators must of necessity be considerably naller than those of a rectangular waveguide attenuator the same frequency range.

Various means may be employed for continuously djusting the position of the loss material in the attenuator ructure in order to vary the attenuation value. Methods mploying lossy cards, and the use of volumetric rather an surface lossy material, are shown in Figure 4.

Figure 5 shows a model of a coaxial variable attenuator the movable resistive vane type. The attenuation and SWR characteristics of this type of attenuator are shown Figure 6. The maximum attenuation values increase ap-roximately linearly with frequency, in agreement with e behavior expected of this type of dissipation mech-ism. It is seen that rather high attenuation values can achieved at the higher frequencies. The values of SWR obtained are quite low in both the "open" and losed" positions, by which is meant the positions for ero" attenuation and maximum attenuation, respectively.

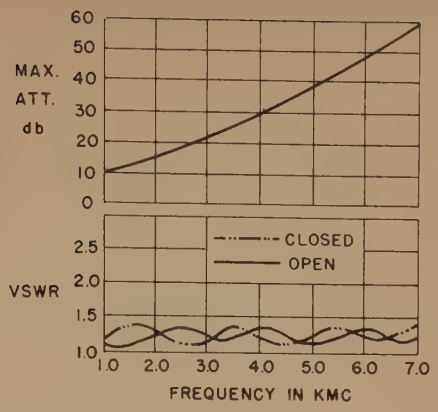


Figure 6 — Attenuation and VSWR characteristics of resistive vane coaxial attenuator.

Similar VSWR characteristics are also found for all intermediate settings. The low VSWR values in the "open" position are made possible through the design of wideband transitions from the circular coaxial line to the ridge coax line. The low VSWR values in the "closed" position are achieved by designing suitable tapering and equalizing sections in the resistance card.

Figure 7 shows a model of a coaxial variable attenuator of the volumetric loss type shown in Figure 4 (c). The attenuation and VSWR characteristics for this model are shown in Figure 8. Again, very high maximum attenuation values are obtained, together with low VSWR values. The usable relative bandwidth of this attenuator is seen to be extremely large: attenuation values of 15 db or higher are obtained over the frequency range from 600 mc to 6000 mc — a decade range.

It is also of interest that the variation of maximum attenuation with frequency is somewhat different from that found in Figure 6. By suitable designs in volumetric type attenuators, it is possible to compensate for the variation of attenuation with frequency. The attenuation characteristics for such a compensated unit are presented in Figure 9, and a particular model is shown in Figure 10. This model was supplied with an in-line drive mechanism and a calibrated dial for convenience in a particular application. Units with such flat attenuation vs. frequency

Figure 7 — Coaxial variable attenuator using volumetric loss material (Model AU-10).

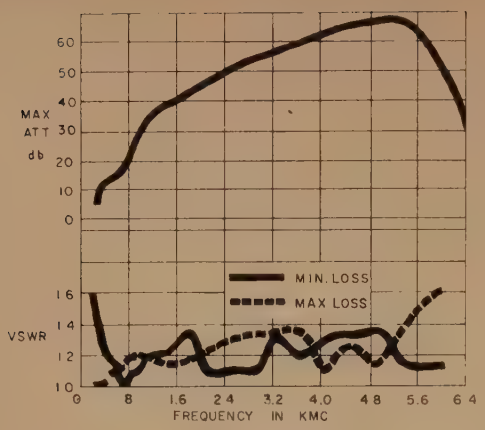


Figure 8 — Attenuation and VSWR characteristics of volumetric loss type coaxial variable attenuators.

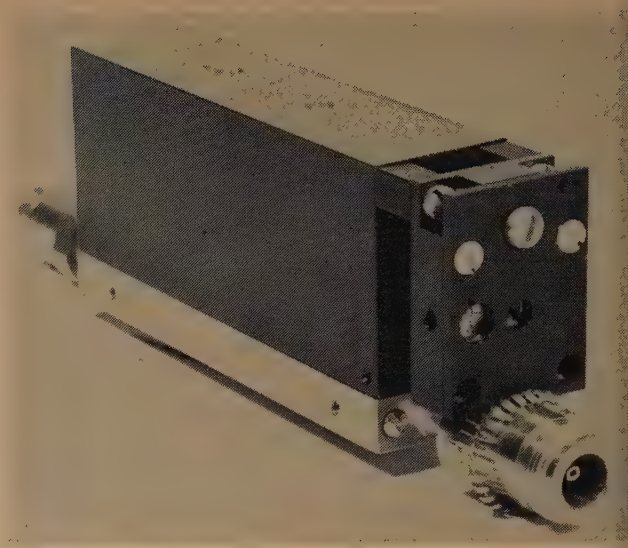


Figure 10 — Coaxial variable attenuator of the compensate volumetric type with in line drive and direct reading cal bration.

characteristics have been constructed for octave bandwidth ranges in both C and X band.

Typical dimensions of actual models are shown in Figure 12. The curves of maximum attenuation vs. frequency (Figures 6, 8, and 9) were obtained from models corresponding to these dimensions. A comparison of the maximum attenuation with the dimensions of Figure 12 indicates the ability of these structures to produce very high attenuation values in relatively short lengths and with small cross-section. The addition of the ridge furnished the means which allowed the high values of maximum attenuation to be obtained. In all cases the lines used were of 50 ohm characteristic impedance.

It should be added that the "zero attenuation" insertio loss was less than 0.5 db for all the types described abov for all frequency values shown. At the lower frequencie the insertion loss was typically less than 0.25 db.

Typical calibration curves of the attenuation vs. inse tion depth are shown in Figure 11 for two types of a tenuators which employ volumetric loss. The calibratio frequency for the model labeled AU-10 is 3000 mc whil that for model AE-6 is 5100 mc. Model AE-6 is of th flat attenuation type. It is seen that for the AU-10 th attenuation rate is slow for small attenuations but tha the variation is approximately linear from 10 db to 40 d The response is more uniform for the model AE-6, an its curve does not possess as sharp a knee as that for mod AU-10.

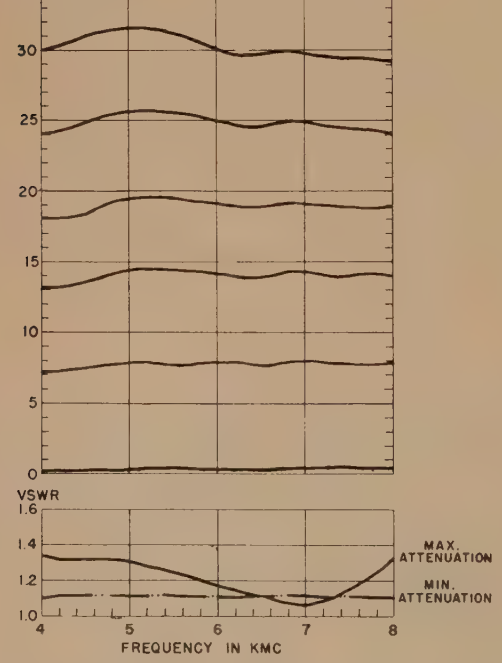


Figure 9 — Typical attenuation and VSWR characteristics of a compensated volumetric loss attenuator for various attenuation settings.

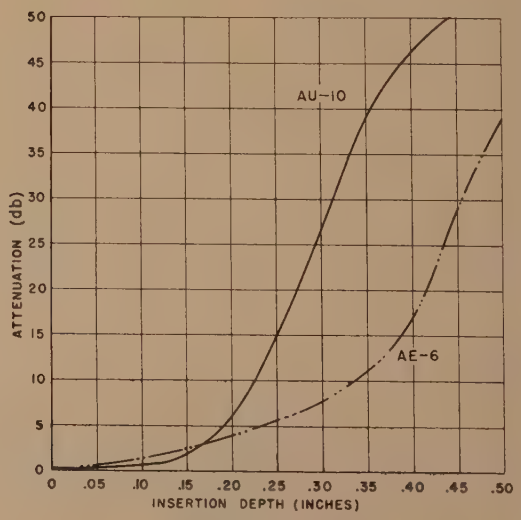
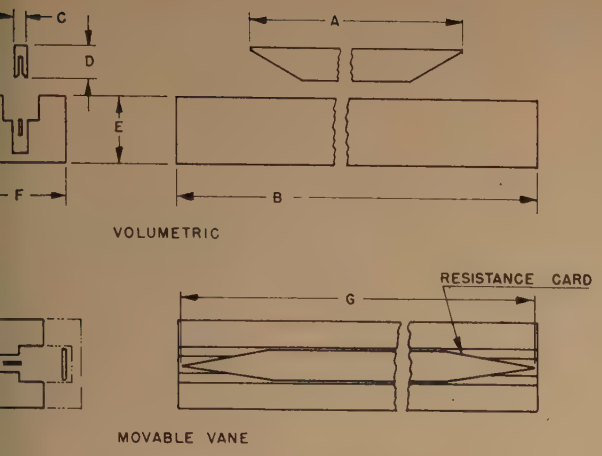


Figure 11 — Typical calibration curves of attenuation insertion depth.



TYPE	MOVABLE VANE	VOLUMETRIC	
		UNCOMPENSATED	COMPENSATED
DIM. A	——	5.70	2.84
B	7.34	7.34	3.67
C	——	.17	.10
D	——	.38	.28
E	.75	.75	.38
F	1.0	1.0	1.0
G	7.31	——	——

(DIMENSIONS ARE IN INCHES)

ıre 12 — Typical dimensions of various attenuator models.

The use of ridge coax lines thus permits the development of novel coaxial variable attenuators with essentially zero initial loss and very high maximum attenuation values for each of the various methods discussed for introducing the loss material. In all methods, continuous and smooth adjustment of attenuation was obtained, and the attenuators are useful over quite broad frequency ranges. Finally, appropriate designs* employing the volumetric type of loss material indicate that flat attenuation vs. frequency behavior can be obtained over octave bandwidths, and that such designs permit attainment of low initial loss.

Acknowledgment

The writer wishes to acknowledge the participation of other staff members of Merrimac Research and Development Laboratories, Irvington, New Jersey, in several phases of the developments discussed in this paper.

*The particular loss mechanisms involved in the flat attenuators are physically significant, and a proper description of the loss material fabrication would elaborate this paper beyond the initial scope intended. It is anticipated that this will form the basis of a later paper.

CORRECTION

A number of typographical errors, detailed in the following, appeared in Part I of the paper "Microwave Radiometry," as published in the April issue of the MICROWAVE JOURNAL:

In equations (14), (15), and (17), "P_λ", appearing on the right-hand side of these equations should have been "p_λ". "P_λ" is defined as the total power received by the antenna, while "p_λ" is defined as the power emitted by a unit area of the emitting body per unit solid angle.

"T" should be inserted following "k" in the numerator of the first factor on the right-hand side of Equation (20).

In Equation (27), "$P_{G\lambda}$", appearing on the left-hand side of the equation should be "$p_{G\lambda}$".

In Equation (31), "P_t" should be "P_1".

Equation (39) should read as follows:

$$P_R = 2k\Delta f \frac{1}{4\pi} \int_\Omega [1 - m(\theta,\phi)] \left[\int_o^d e^{-2\int_o^z \alpha(\theta,\phi,z)dz} \alpha(\theta,\phi,z)T(\theta,\phi,z)dz \right] G(\theta,\phi)d\Omega.$$

We regret any inconvenience caused our readers and the author.

MICROWAVE ENGINEERING ASPECTS of ELECTRON LINEAR ACCELERATORS

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Harvard University · Cambridge, Mass.

PART II

Introduction.

In part 1 of this review[1] some of the theoretical aspects of accelerating waveguide structures for electron linear accelerators were discussed and it was shown how an electromagnetic wave can be propagated with an axial electric field component travelling with a phase velocity equal to that of light, c. This is the principal feature of all modern linear electron machines.

It is the purpose of the present article to deal with engineering and operational aspects, including electron injection, the development of microwave power sources, mechanical problems and, in conclusion, the arguments and proposals for the construction of multi-mile multi-billion volt machines. Of necessity, the scope of the discussion is limited and the reader is referred to a list of references for a more detailed study of the subject.

Electron Injection

Analysis of the optics of electron injection into the accelerator waveguide and of the subsequent electron trajectories through the machine shows, that unless certain precautions are taken, only a fraction of the injected electrons will absorb energy from the rf accelerating field, and the emerging electron beam will have a broad energy spectrum. It is necessary, therefore, to consider methods to improve both the acceptance of injected electrons and the energy spectrum since these parameters significantly determine the usefulness of any given accelerator.

In order to simplify the electron gun design, it may be desirable to inject at comparatively low voltages. Thus, for a gun voltage of 79 KV in the Stanford Mark III accelerator,[2] the velocity of the injected electrons is only 0.5c and some means must be found to accelerate these close to c, the velocity of light. It may be appropriate to point out at this stage, that an increase of the velocity of electrons occurs only up to an energy of about 2 Mev, where electrons move essentially at the velocity of light; any further increase of energy appears as an increase of electron mass. For this reason, multi-Mev electron machines might be described more appropriately as m multipliers. A disc-loaded section of waveguide design to give a gradual increase of phase velocity for initial celeration to c is shown schematically in Figure 1, wh the degree of loading is changed gradually with axial d tance from the electron gun. At the same time the fi strength is increased, the net result being the formation tight bunches of electrons which then enter the const velocity (v_p=c) main accelerator waveguide.

For electrons injected from guns operating at high voltages (200 KV, say), a somewhat simpler scheme m be used to improve acceptance and energy spectrum. T consists of a klystron-type buncher cavity whose funct is to modulate the velocity of the beam of injec electrons which are initially uniformly distributed in pha so that on entering the accelerator they are grouped wit a narrow phase angle of the accelerating rf field. The mo lation is phased such that early particles are retarded a late particles accelerated. A suitable drift space is p vided so that the velocity changes cause appropriate chan in current density and phase. In a typical injection syst with a 200 KV gun and a drift length of 35cm, optim bunching occurs with a velocity modulation amplit of 3%, requiring a buncher cavity voltage of 20 K which with a properly designed cavity, operating at 3 mc, requires a peak power of only a kilowatt. Both, tapered section and the cavity type buncher, are used practice.

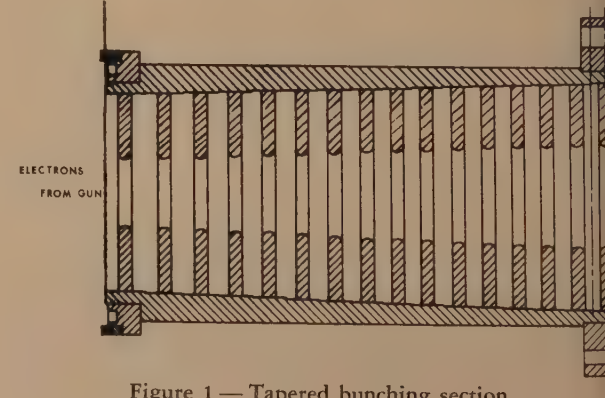


Figure 1 — Tapered bunching section.

* Dr. Barrington is now Manager of Research, Vacuum Products Division, Varian Associates, Palo Alto, California.

igure 2 — Launching of TM_{01} made in circular waveguide.

Since most modern machines are powered by klystron nplifiers which are discussed in the following section, is possible to make the klystron an integral part of the achine. A fraction of the bunched beam current which is ormally intercepted by the klystron collector is then in-cted into the accelerator. This constitutes some saving in onstruction and circuitry costs but requires special con-nuously evacuated klystron tubes.

It is necessary to provide adequate axial magnetic fo-ussing at injection. The magnetic field is critical only ver a short distance and becomes less as the electron veloci- approaches c. It is desirable to provide some magnetic ocussing over the whole length of the machine to control he beam cross-section and also to compensate the deflect-ng effect of the earth's magnetic field, which may be con-eniently reduced by static magnetic shielding.

ower Sources

The design frequency of accelerators in use at present as governed by the availability of power sources de-eloped for microwave Radar. The most powerful tubes onstructed at the end of World War II operated at 000 mc. It turns out that the shunt impendance per unit ngth of the accelerator structure varies as $\lambda_0^{-1/2}$ which dicates that the shortest wavelength should be used con-stent with the power available at this wavelength. It is esirable, that the quantity $P\lambda_0^{-1/2}$ should be a maximum, here P is the available tube power and λ_0 the free space avelength. This consideration, as well as cost figures nd constructional problems, indicates that the choice of 000 mc was fortunate, although it will be shown later hat operation at lower frequencies may be desirable for achines operating at high intensity and long pulse dura-on.

It was stated in Part I of this review that, in order to eet the competition of the betatron, multi-megawatt pow- sources were required to provide the necessary acceleratg fields for linear electron machines. The only tube with is capability was the magnetron which, being a self-scillator, did not lend itself in a satisfactory manner to arallel operation. This becomes particularly serious in achines exceeding a few Mev where it is essential to sub-vide the accelerator into independent sections, each be-g powered by a separate power source. For satisfactory peration, phase coherence between these power sources imperative and a system consisting of a master oscillator nd individual power amplifiers has obvious advantages. his was recognized by the Stanford group, who in a re-arkably short time completed a successful design of multi-egawatt klystron amplifiers.[3] Klystrons had been used in rge numbers during World War II, but mainly as low-vel devices and little was known about the electron optics nd the mechanism of klystron operation at relativistic ectron velocities. The Stanford group successfully ob-ined a peak power of 14 megawatts from a single tube in 1949. One thus finds that, stimulated by the demands of accelerator builders, a new method of generating multi-megawatt pulses of microwave power became available; in parallel with this development grew a technology of power supplies, pulsers and triggered spark-gaps and switches.

During the last ten years there have grown new industries based on the development of multi-megawatt tubes and transmitting equipment and, unlike the early continuously pumped klystrons, sealed off tubes are now readily available commercially.

A new high-power microwave amplifier, the Amplitron,[4] whose development may be significant for accelerator operation has recently been described in the literature. This is a crossed-field magnetron-type tube quoted as operating at a power level of 3 megawatts peak and 15 kilowatts average at 3000 megacycles. Unlike the klystron, whose gain is usually between 40-50 decibels, the Amplitron gain is of the order of only 10 decibels. The device has, however, several attractive features, such as a high efficiency (75% as compared with 30-40% for klystrons), low operating voltage (50 KV), good phase and pulse stability, capability of heaterless operation and, since the electron current is maintained by secondary emission only, capability of long pulse operation. These characteristics appear to be very advantageous for linear accelerator rf systems.

Mode Convertors.

The simplest method of exciting the TM_{01} mode in a waveguide of circular cross-section is shown in Figure 2, where power is transferred directly by means of a probe formed by the center conductor of a coaxial cable. In this form the device is unsuitable for accelerators, since it does not permit electrons to enter axially into the guide; furthermore, most modern high power microwave tubes have waveguide rather than coaxial outputs and the problem resolves itself into the conversion of the TE_{10} mode in rectangular to the TM_{01} mode in circular waveguide.

A simple transition[5] to accomplish this for a metal disc-loaded accelerator is shown in Figure 3a; this is not suitable for dielectric loaded waveguides which are capable of supporting unwanted TE modes; by increasing the length of the feed with a length of coaxial line[5] (below cut-off for modes other than the principal mode), direct coupling between TE modes in the two waveguide systems is suppressed (Figure 3b). Even so, matching between the two systems is difficult and a more elegant solution[5] which is less sensitive to mechanical changes is shown in Figure 3c. In early machines it was found convenient to make the input waveguide part of the accelerator vacuum system; this obviated the need for a vacuum tight waveguide window at the transition and prevented dielectric breakdown of the

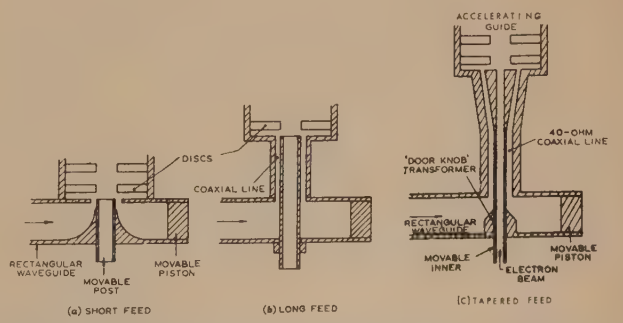
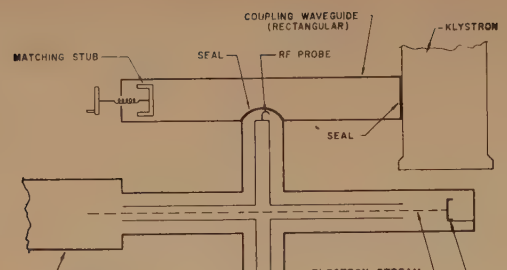
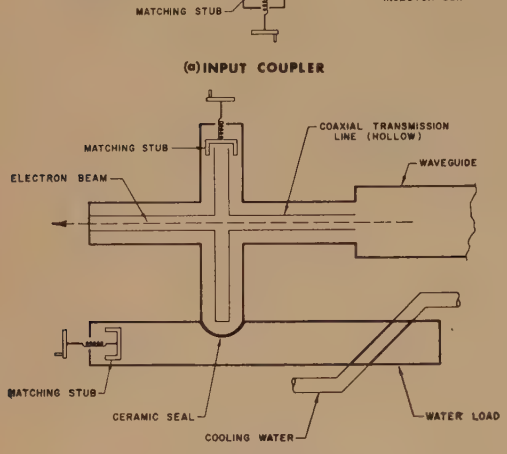


Figure 3 — Rectangular to circular waveguide transitions for accelerators.



(a) INPUT COUPLER



(b) OUTPUT COUPLER

Figure 4 — Typical rf input and output couplers.

waveguide under high peak power conditions. However, the performance of windows has been improved so considerably that it is now possible to isolate the accelerator vacuum system; the rectangular waveguide between klystron and mode converter is pressurized. A typical system for a travelling wave machine is shown in Figures 4a and b, which are self-explanatory. Flexibility of matching is obtained with the two matching stubs shown.

Mechanical Problems.

Since all large machines in present use utilize metal disc-loaded accelerating waveguides, the discussion of constructional features will be limited to this type. In early machines, the discs were secured in the accelerator tubing by soldering. In spite of the use of oxygen-free high-conductivity copper, such structures were found to have excessive rf losses. These disadvantages were largely overcome by means of a shrinking technique,[2] resulting in an improvement of the Q-factor from about 3000 to 10,000. Briefly, the shrinking operation consists of increasing the diameter of a precision-bored circular tube by means of a steam jacket and reducing the diameter of the loading discs by cooling in liquid nitrogen. The discs are spaced the correct distance apart by means of an invar mandrel. They are firmly secured in the circular tube on reaching room temperature.

This method is entirely satisfactory for waveguides of about 3 feet in length and there are several possible alternatives suitable for the production of longer sections. Either, the complete waveguide structure may be electroformed in its entirety, or, copper may be electro-deposited onto a mandrel formed by stacking machined copper irises and spacers of aluminum, resulting in a considerable saving in machining effort and cost. It has also been suggested that good vacuum and rf performance may be obtained by stacking an assembly of irises and short cylinders whose ends are indium-plated and enclosing these in a stainless steel cylinder which serves as an axial clamp and as a water jacket.[6]

In order to appreciate the necessity of temperature control during operation as well as close tolerances during manufacture, it is important to realize that the constant phase-velocity section ($v_p = c$) is so designed that the electron bunches travel at the peak of the accelerating field. This yields the maximum energy gain and minimizes frequency sensitivity. The dimensional limits required for this purpose may be determined experimentally by a measurement of the change of frequency of the desired operating mode which occurs when one dimension of the disc-loaded guide is varied. Typical results, with reference to Figure 5 are[6]:

$$\partial f/\partial B \sim -1 \text{ mc}/0.001 \text{ inch}$$
$$\partial f/\partial A \sim +0.25 \text{ mc}/0.001 \text{ inch}$$
$$\partial f/\partial d \sim -0.1 \text{ mc}/0.001 \text{ inch}$$
$$\partial f/\partial p \sim +0.25 \text{ mc}/0.00\text{-} \text{ inch}.$$

On the other hand, a change of waveguide temperature of 20°C, taking the expansion coefficient of copper to be 17×10^{-6}, leads to a change of operating frequency of approximately 1 mc for a design frequency of 3000 mc.

The frequency sensitivity of an accelerator waveguide in terms of electron energy[6] is shown in Figure 6, from which it may be seen that a 1°C temperature change leads to an energy decrease of approximately 1%. It is also apparent that the tolerances on all mechanical dimensions should be specified to limit the frequency excursions to not more than 0.1 mc. For economic reasons, a compromise solution may be accepted by incorporating a temperature control system whose range is sufficiently wide to compensate any uncertainties of machining tolerances.

An important feature of the mechanical design is the vacuum system, since it is necessary to evacuate the accelerator tube to a sufficiently low pressure to avoid excessive scattering of the electron beam and rf breakdown in the accelerating waveguide. A pressure of less than 10^{-5} mm of mercury is required for satisfactory operation.

Since the conductance of the waveguide for molecular flow is very low, pumps with a pumping speed of the order of 50 litres per second at each end of a ten foot section are adequate. It is important to prevent the diffusion of pumping fluid into the machine, since contamination of the waveguide surface with pump oil can lead to break-down under high electric field operation. For this reason, care-

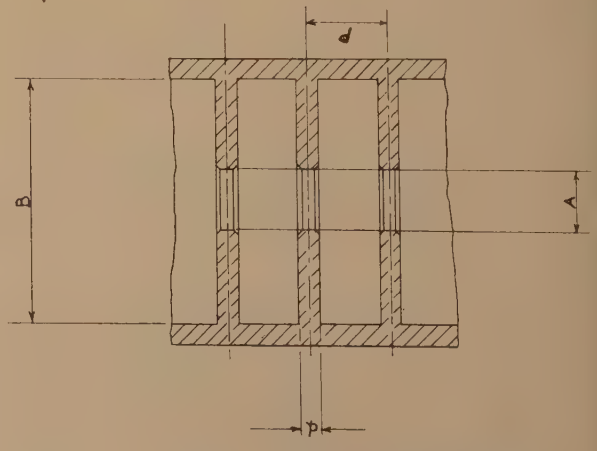


Figure 5 — Typical disc-loaded waveguide sections.

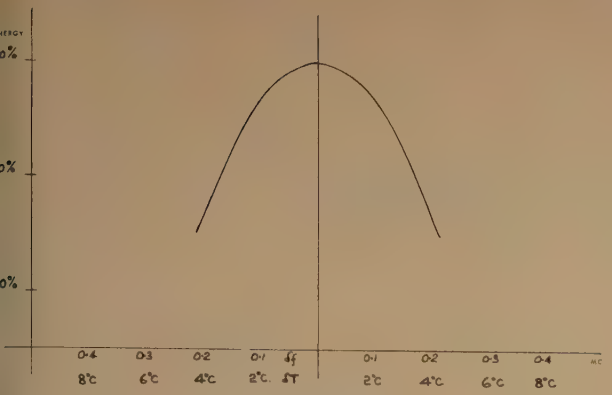


Figure 6 — Frequency dependence of electron energy.

trapping is necessary and liquid nitrogen or activated per traps are used in practice. The vacuum system can greatly simplified by using getter pumps which have ently become available commercially. Since there is no mping fluid, trapping is unnecessary and no special pre- tions are required in case of power or cooling water ure, as are necessary for diffusion pumps.

erational Problems of High-intensity Machines.

Until recently, the principal objective of accelerator lders has been the attainment of electron energies ap- aching one billion electron volts as envisaged for the nford Mark III machine. The current delivered under se conditions (50 ma peak during a 0.3 microsecond se[7]) is sufficiently small so as not to lower the ac- erating field very appreciably. For economic reasons it dvantageous to operate machines designed for the pro- ction of high intensity radiation at high currents of g pulse duration. Under this condition, the guide fields reduced considerably by the beam — this is termed am loading" — and with constant input power the elec- n energy depends largely on the amplitude of the beam rent. A typical oscillogram of the power at the output l of a travelling wave machine is shown in Figure 7, ere the effect of the beam on the envelope of the rf pulse clearly shown.

t has been observed, that regardless of the duration of injected electron beam pulse, the pulse length of the put beam depends on and shortens with increasing am- ude of the injected current; it has been called the "pulse- rtening" effect. This phenomenon limits the useful rge per pulse and no entirely satisfactory theoretical ex- nation has so far been put forward. In practice, it is nd that by making the accelerator short, increasing the power, or applying a large axial focussing field, pulse- rtening is prevented. For high energies this requires a ger number of sections in tandem and the resulting com- xity involves an increase in cost. A more attractive ution of the problem[8] seems to be the use of an acceler- waveguide operating at the same power level but at 00 mc (L-band) rather than at 3000 mc (S-band). For same electron energy this machine is electrically shorter offers great promise, since L-band high-power klystron plifiers are now available commercially. It is claimed whereas the pulse length of a high intensity S-band chine is limited to 5 microseconds, an L-band machine vers 30 microsecond pulses with no apparent pulse- rtening.

t has been suggested[9] that "pulse-shortening" may be

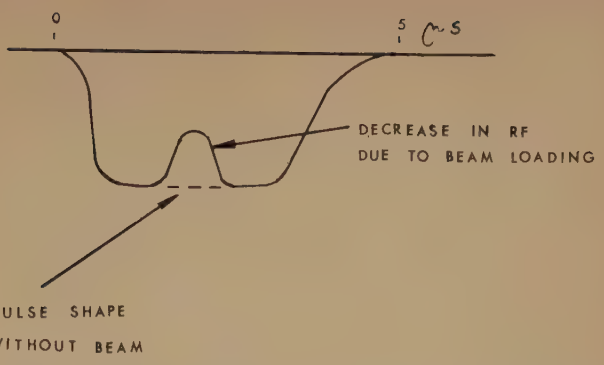


Figure 7 — Typical envelope of rf pulse with and without beam loading.

due to transfer of rf energy by the electron beam from the accelerating fundamental waveguide mode to a higher frequency mode. This may be understood by considering Figure 8, a more detailed explanation of which was given in Part I of this review[1], where it was shown that the slope of the radius vector from the origin 0 to any point on the diagram is proportional to the phase velocity, v_p, corresponding to a given value of frequency and propagation constant. Thus, the radius vector shown intersects all pass-bands, which implies that there is an infinite number of modal frequencies with the same phase velocity. The group velocity, $\frac{v}{g}$, of these modes, being proportional to the slope of the tangent of the curve at the point of intersection, may be positive or negative, denoting a forward or backward wave component. It is conceivable that a higher frequency mode is excited by the beam which builds up exponentially (a mechanism similar to that of the backward wave oscillator) by bunching the beam and extracting energy from it. The defocusing effect of the radial electric field component of this mode then causes break-up of the beam in the first few feet of the accelerator. Experi-

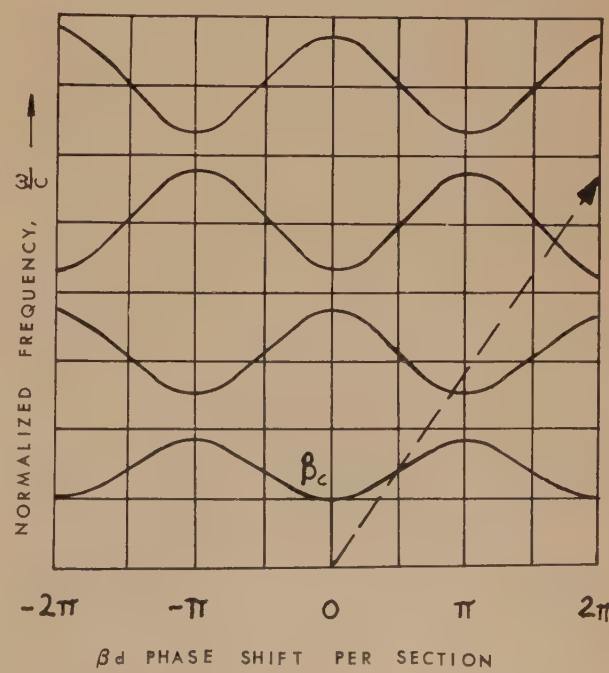


Figure 8 — $\frac{w}{c}$ — βd diagram for waveguide with periodic obstacles a distance d apart (dashed line is radius vector from origin 0).

mental evidence that this effect does not occur in physically or electrically short accelerating sections and can be overcome with very strong axial magnetic focussing fields tends to support this theory.

Conclusion

Billion-volt (Bev) Accelerators.

It is fortunate that sufficient information is now available to conclude this review with an outline of proposals for electron linear accelerators several miles long designed for multi-billion-volt operation.

The scientific objectives that are envisaged with such machines are[10]: (1) The controlled artificial production of particles which are otherwise only produced in very low intensity from cosmic rays; (2) the production of particles to explore nuclear structure and to study the interactions of these particles in nuclear matter; (3) to provide a tool for the study of the basic production process in the creation of particles; (4) to provide a tool for the study of the high-energy limits of quantum electrodynamics.

Circular machines for the production of electrons with energies up to 6 Bev are now under construction at Harvard University[11] (CEA) and in Hamburg, Germany (DESY), with a design objective of 10^{11} electrons per pulse. The practical energy limit of a circular machine (electron synchrotron) is associated with the rapid increase of energy loss by radiation in the circular orbit at high energies. The radiation loss, L, per electron in electron volts per turn is given by[12] $L = \frac{4\pi}{3}\frac{e^2}{r}\left(\frac{V}{m_0c^2}\right)^4$, where e is the electronic charge, r is the radius of the orbit, V is the total energy of the accelerated electron and m_0c^2 is the electronic rest energy. For a typical machine the following values are obtained:

Energy, V (Bev)	Radiation loss, L (Mev/turn)
5.0	3.32
6.0	5.73
8.0	13.6
10.0	26.5

In estimating the practical limit of such a machine, an important factor is the cost of the rf system, necessary to make good this radiation loss, which becomes prohibitive above some energy region in comparison with other components.

On the other hand, the ratio of the energy lost by radiation to the energy gained by an electron in a linear accelerator is[13] $\frac{2}{3}\frac{Eea}{m_0c^2}$, where a is the classical radius of the electron ($e^2/m_0c^2 \sim 2.8 \times 10^{-13}$cm) and E is the accelerating field. The loss becomes serious only if the energy gained by the electron in travelling through a distance equal to its radius (Eea) is comparable to its rest energy ($m_0c^2 \sim 0.51$ Mev).

In the Stanford Mark III accelerator, this loss/gain ratio is $\sim 10^{-13}$ which may be neglected for all practical purposes. Unlike the situation in a circular machine, the ratio is independent of electron energy and there is therefore no theoretical or practical limit imposed by radiation considerations.

It turns out that a circular machine cannot compete on an economic basis with a linear accelerator above about 10 Bev. The linear machine can also deliver higher and more sharply focussed beams than a circular accelerator.[14]

The maximum energy gradient that can be supported by a conventional metal disc-loaded waveguide is considered to be about 60 Mev/metre. The Stanford Mark III machine operates at an average gradient of 15 Mev/metre. A machine 2 miles long could therefore accelerate electrons to an energy of 45 Bev and would require 920 klystrons capable of a peak power output of 22 megawatts.[10] It is proposed to construct a machine of this type on the grounds of Stanford University, Palo Alto, California. For shielding purposes it has to be situated underground in two parallel tunnels, one for the accelerating waveguide and one containing the klystrons and associated equipment. An engineering study has demonstrated the feasibility of such an installation. It is beyond the scope of this survey to discuss in detail the numerous engineering problems encountered in a project of this magnitude, but there seems to be no upper limit to the energy that can be achieved by an increase of accelerator length or klystron power.

In just over 10 years, the concept of a waveguide type electron accelerator has thus been advanced from the pilot stage to an important commercial product as well as an invaluable research tool to probe into the nature of matter, with an increase of energy of more than three orders of magnitude. This is an achievement which is largely due to the growth of the microwave art during the decade; it has not only brought about spectacular progress in the field of communication engineering but will provide a key to a better understanding of nuclear forces with the most powerful electron machine so far conceived by high-energy physicists.

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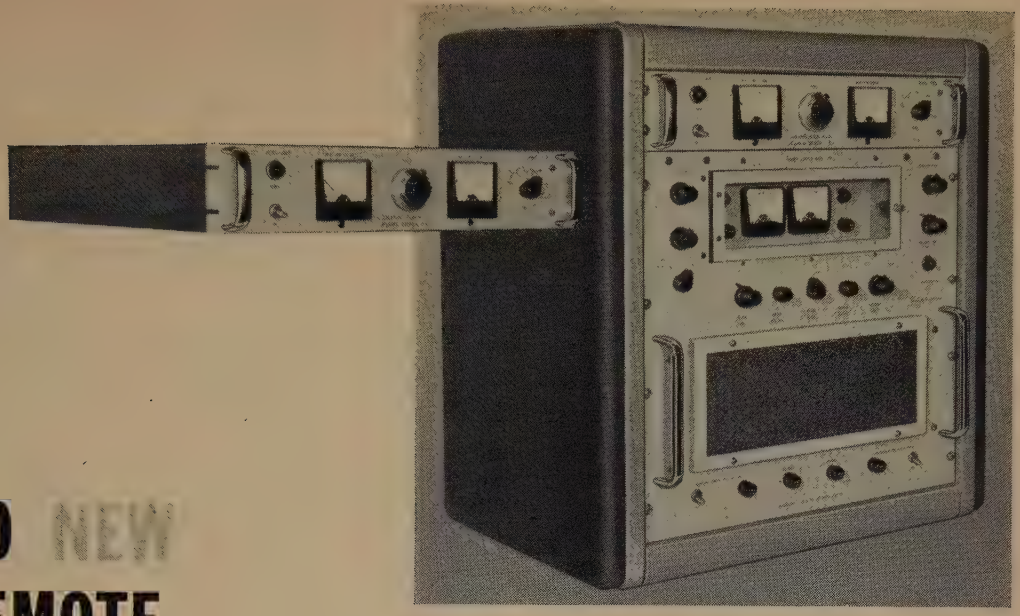


Model SS 20 Signal Source Power Supply with Tuning Unit. Tuning Unit is removed to control position for remote operation. Inset shows unit removed for remote operation. In this mode, control unit can be operated up to one mile away.

TWO NEW REMOTE TUNED SIGNAL SOURCES

(50 mc to 2 kmc, and 1 to 37.5 kmc)

Now Scientific-Atlanta offers two remote tuned signal sources which provide complete frequency coverage from 50 mc to 37.5 kmc. These sources are primarily designed for use as transmitters for antenna test ranges but find many other applications where remote tuning at distances up to a mile or more is required.

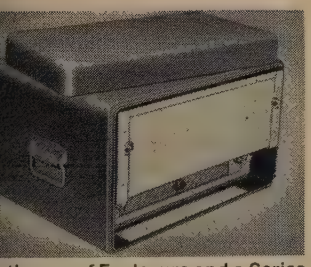
MODEL SS 30 (50 mc to 2 kmc)

Contains three GR Unit Oscillators mechanically ganged and servo driven. • RF output capable of being sine or square-wave modulated. • Frequency accurately resettable to within ±0.5%.

MODEL SS 20 (1 to 37.5 kmc)

Extended frequency coverage with seven Series RFO Oscillator Units. Integral-magnet backward wave oscillators are voltage tunable and require no mechanical peaking. • RF output capable of being square-wave modulated. • High signal purity, low residual fm. • Will operate cm and mm-wave klystrons. • Remote tuning unit will also operate SS 30 Signal Source.

KEY SPECIFICATIONS	MODEL SS 30	MODEL SS 20
Frequency Range	50 mc to 2 kmc	1 to 37.5 kmc
Tuning Chart Accuracy	±2%	±5%
Frequency Resettability	±0.5%	±0.1% or 5 mc, whichever is greater
Power Output	80 mw into 50-ohm load	see table of RFO Oscillators



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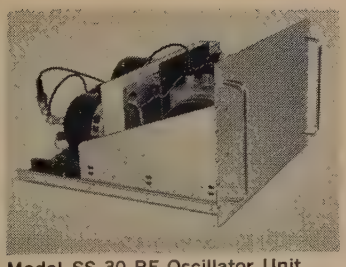
O Oscillator Unit.



Model SS 30 RF Oscillator Unit

SERIES RFO OSCILLATOR UNITS

MODEL	FREQUENCY RANGE	OUTPUT POWER
RFO 1	1.0 - 2.0 kmc	40 - 800 mw
RFO 2	2.0 - 4.0 kmc	100 - 800 mw
RFO 3.6	3.6 - 7.2 kmc	5 - 300 mw
RFO 7	7.0 - 11 kmc	20 - 300 mw
RFO 8.5	8.5 - 16 kmc	5 - 100 mw
RFO 15.5	15.5 - 24 kmc	5 - 125 mw
RFO 23.5	23.5 - 37.5 kmc	5 - 100 mw

PRICES

Model SS 30, $3,850; SS 20, $3,550; SSG 1 Sine-Square Wave Generator, $350; RFO 1, 2 and 3.6, $1,400; RFO 7, $1,900; RFO 8.5, $2,060; RFO 16, $3,330; RFO 23.5, $3,330. For more details, please contact your S-A representative or write directly. Address Dept. 69

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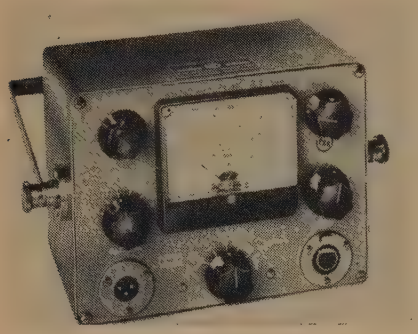
Circle Reader Service Card 32

New Products

TRANSISTORIZED POWER METER OFFERED BY FXR



The FXR Model B832T Transistorized Temperature Compensated Power Meter is a compactly packaged instrument which will accurately measure either CW or pulsed RF power in five full scale direct reading ranges from 30 microwatts to 3 milliwatts. Values can be read in MW or DBM. The instrument incorporates a method of controlling the accuracy and stability of RF power measurements. Readings are virtually drift free; compensation of ambient temperatures makes the instrument more stable than comparable measuring devices, even in the 30 microwatt range. Provision is made to calibrate the DC voltage at all levels and the bridge is self-balancing at 200 ohms. Range switching without recalibration is another advantage.

FXR Model B832T Transistorized Temperature Compensated Power Meter is energized by a self contained rechargeable nickel cadmium battery. The charging circuit operates from a 105 to 125V ac, 50 to 400 cps source. The use to charge ratio is 2 to 1.

An FXR Series 218 Thermistor Head is a required accessory.

Circle Reader Service Card 101

—mwj—

HIGH POWER SWITCH ATTENUATOR

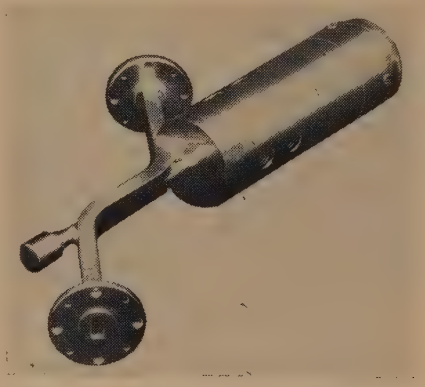
Bogart Manufacturing Corp., Brooklyn, N.Y., has designed a high power switch attenuator which makes available, to the antenna, two different power levels. When the switch is deactivated, the power fed in is seen at the output with less than 0.6 db insertion loss. When the switch is activated, the input power is attenuated by a factor dependent on the value of attenuation designed into the high power attenuator.

This attenuator can be supplied in values ranging from tenths of a db to 20 db and up. The unit is supplied with a high power isolator and, in most applications, may be switched without turning off the transmitter. The switch is supplied with an external holding resistor, allowing indefinite periods of actuation without excess heating of the switch mechanism. The unit is pressurizable and is available for most frequency ranges and waveguide sizes.

Circle Reader Service Card 102

—mwj—

NEW 40 KMC GAS TUBE NOISE SOURCE ANNOUNCED



Another addition to the line of gas tube noise sources produced by Tucor, Inc., South Norwalk, Conn., has been announced.

Designated the T44QIB, the noise source operates at a frequency range from 26.5 to 40.0 kmc and is capable of producing up to 18 db above KTB. Housed in a waveguide structure which allows for minimum length and voltage requirements, the noise source is suitable for cw or pulse operation under typical adverse military environments. It meets all applicable military requirements.

Other specifications of the T44Q1B are: operating current, 45 ma; filament voltage, 6.3±5% volts ac or dc; filament current, 1.25 amps (nominal). It also employs firing voltage (negative to cathode) of less than 2000 volts and operates at 250 volts maximum.

Circle Reader Service Card 103

—mwj—

NEW DEWAR SHEDS NEW LIGHT ON NUCLEAR RESEARCH

A Hofman 3-liter, liquid helium stainless-steel research dewar, installed at Bell Telephone Laboratories in Murray Hill, N.J., is used for nuclear magnetic resonance studies of magnetic materials, including ferrites, phosphorous

compounds, etc. A copper radiation shield is at the base of the dewar.

This dewar is the product of Hofman Laboratories, Inc., Hillside, N.J., designers and producers of liquid helium research dewars for microwave spectrometry, superconductivity studies, low temperature chemistry and nuclear research. A 44 page catalog with engineering data is available.

Circle Reader Service Card 104

—mwj—

MINIATURE PILL VARACTOR DIODES FEATURE UP TO 120 KMC CUT OFF

A series of five miniature pill varactor diodes with outside dimensions of 1/8" x 1/8" and cut-off frequencies through 120 kmc are now available in experimental quantities from Microwave Associates, Inc., Burlington, Mass.

One of the major uses for the new miniature varactors is in traveling-wave broadband parametric amplifiers at frequencies through X-band for the highest cut-off types. The diodes can be supplied to ±10% capacitance tolerance for such uses.

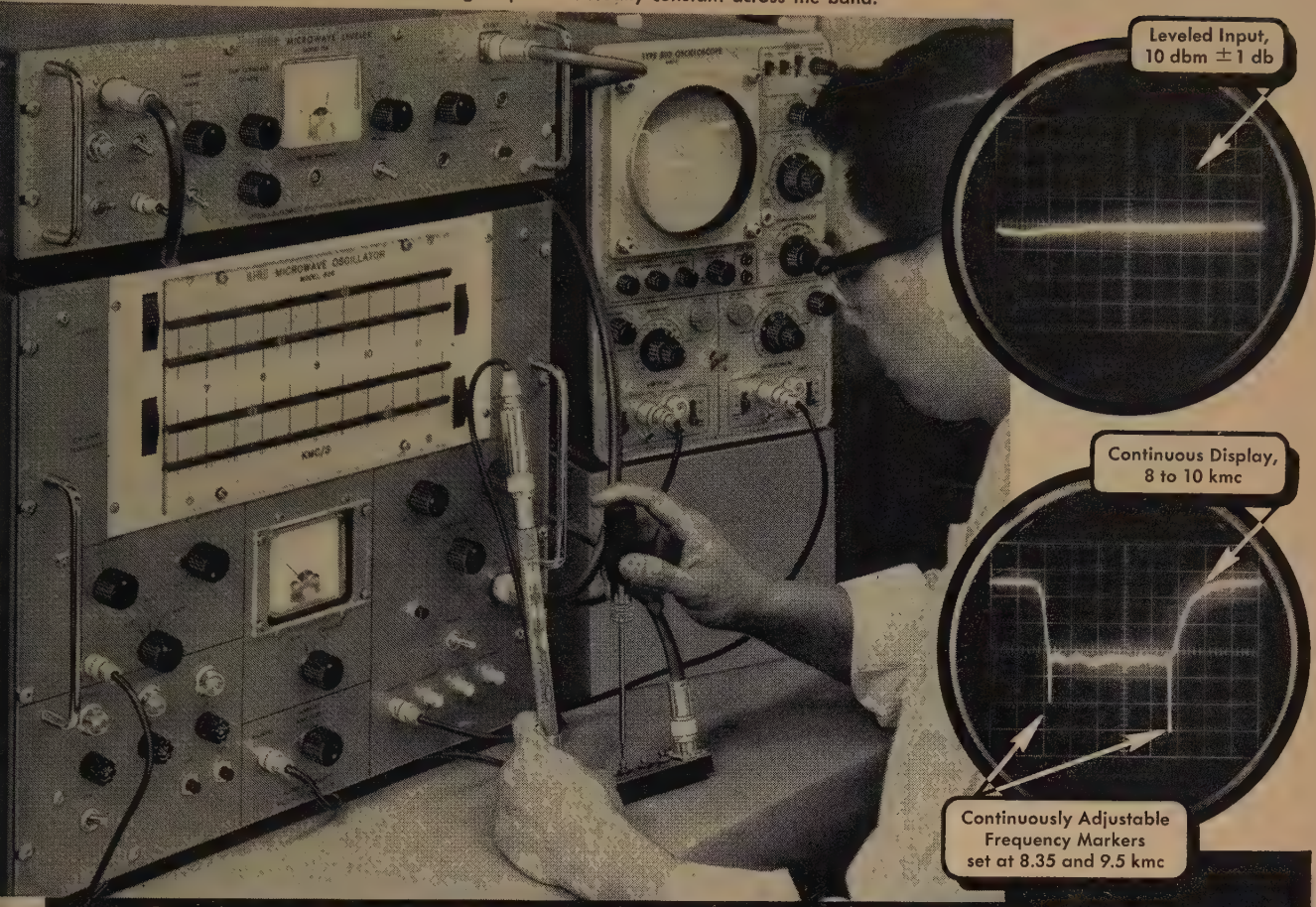
Stray susceptance is kept at a minimum as a result of the close tolerances maintained in fabrication of the units.

As a high frequency harmonic generator, power outputs up to 20 milliwatts are reported in tripling X-band input power to the 35 kmc region.

Circle Reader Service Card 105

(*Continued on page 70*)

esting insertion characteristics of X-band filter with Alfred Swept Generator. It consists of Alfred icrowave Oscillator and Alfred Microwave Leveler. This combination electronically sweeps frequency linearly with respect to time while maintaining RF power virtually constant across the band.



Save Test Time, Assure Test Accuracy

with ALFRED'S new SWEPT Microwave Generator.....

The scope patterns tell the story. Top pattern shows constant power input from Alfred Swept Generator to component (filter) under test. With known input, variation in output is due to filter characteristics. Lower pattern is especially significant, showing continuous, flicker-free display, 8 to 10 kmc. Any changes in stubs or irises are immediately reflected. Measurement accuracy is assured *at every frequency,* not just at selected points.

IS TECHNIQUE CAN BE USED FOR MOST PRESENTLY KNOWN MICROWAVE TESTING PPLICATIONS. HERE'S WHY IT'S FASTER THAN CONVENTIONAL SIGNAL GENERATORS:

Continuous Display allows immediate easurements — no plotting needed. race can be recorded if desired.

Sweep Technique eliminates time-conming "point-to-point" frequency and wer setting methods of conventional gnal generators. Sweep range is continously adjustable with 1% accurate Direct eading Slide Rule Dial.

"Quick Look Readout" eliminates calations in setting sweep range.

Adjustable Frequency Markers allow pid, broadband calibration of scope or corder trace.

SOME MORE FACTS YOU SHOULD KNOW

* *Frequency Ranges.* The Swept Generator is available in five ranges to 12.4 kmc — 1 to 2, 2 to 4, 4 to 8, 7 to 11, 8.2 to 12.4.

* *Stability.* At any single frequency, stability of the Swept Generator equals that of a conventional signal generator. Spurious modulation is low.

* *Power Output.* Greater than a signal generator: 10 milliwatts as compared to 1 milliwatt.

FUNCTION OF THE LEVELER It holds power output constant to ±1 db over standard frequency ranges, and better than ±1 db over narrower ranges. The Leveler serves as a broadband attenuator with up to 20 db dynamic range control, providing constant output over a wide range. It can be used as a general purpose instrument for a wide variety of oscillators and amplifiers.

For more details on the Alfred Swept Generator — please contact your Alfred sales engineering representative, or write direct.

y specifications for Signal Generators available for coverage from 1 to 12.4 kmc

quency—Controls: Continuously adjustable with direct calibrated dial. Calibran accuracy: 1%. Stability: ±0.02%/hr. Residual FM: ±0.0025%. **Power Output** nimum): 10 mw ±1 db. Continuously adjustable from zero to maximum. **enuation Range:** Up to 20 db. **Sweep**—Selector: Recurrent Sweep, Single Sweep, gle Frequency, and External on panel switch. Time: 100 to .01 seconds, conuously adjustable. **Monitor Output**—Sweep Out: Positive linear sawtooth, 45 ts peak. Panel BNC connector. **Amplitude Modulation**—Internal Square Wave: output is alternately 0 and unmodulated CW value. Frequency 800 to 1200 cps, ustable by panel control.

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X-BAND

8.2-12.4 KMC

ELECTRONICALLY SWEPT SIGNAL SOURCE

MODEL 630-X

FREQUENCY:	8.2-12.4 KMC
POWER OUTPUT:	20 MW (Minimum)
SWEEP RATE:	C. W. or 0.1-100 CPS
SWEEP WIDTH:	A few MC to 4.2 KMC
A. M. MODULATION:	800-1200 CPS Sq. Wave
SWEEP OUTPUT:	Linear Sawtooth
OSCILLATOR:	Varian VA-161
SIZE:	7" x 19" x 13"
WEIGHT:	Approx. 25 lbs.
R. F. CONNECTOR:	Type "N" (Female)
PRIMARY POWER:	105-125/1/60
PRICE:	$2,850.00
RACK MOUNT:	$2,825.00
DELIVERY:	1-3 Weeks

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GABRIEL ELECTRONICS

Millis • Massachusetts

BOX SCORE

NAME: Gabriel Electronics, Division of The Gabriel Company.

LOCATION: Main and Pleasant Streets, Millis, Massachusetts.

PRODUCTS: Point-to-point communications antennas; antenna systems; aero-space antennas and ground support antenna systems; feeds and horns; rotary couplers.

HIGHLIGHTS: Gabriel Electronics has established its growth program on two important objectives:

1. To serve the electronics industry by becoming one of the world's most progressive sources of antenna development and supply; and
2. maintain an atmosphere within the division that will stimulate and encourage development of the individual, as well as the growth of the Division.

troduction

It was a little over a year ago that the seeds of a w image for this division were planted. "The results are atifying," said Stanton Yarbrough, new President and neral Manager. "We have consolidated our wide ead operations, straightened the kinks out of our new nt, established policies for confidence in the future for engineers and other employees, and increased our es by 33% in fifteen months."

The new ultra-modern facility at Millis is a prime exple of utilitarian design for the engineer, research cialist, and electronics component manufacturing. Gabriel Electronics' new research, engineering and manufacturing center represents an investment of approximately $2,500,000. It provides the company lower cost production by consolidating operations formerly performed in four widely dispersed locations. It has permitted higher volume of small and medium sized antennas and components, and has eliminated considerable subcontracting.

The new plant is located on an 80-acre site to provide for comfortable expansion to a minimum of 200,000 square feet. At present, six antenna pattern ranges, of 200, 400, 1000, 1200, 2200, and 3400 feet are in operation. Property has been acquired for three additional 4200 foot ranges.

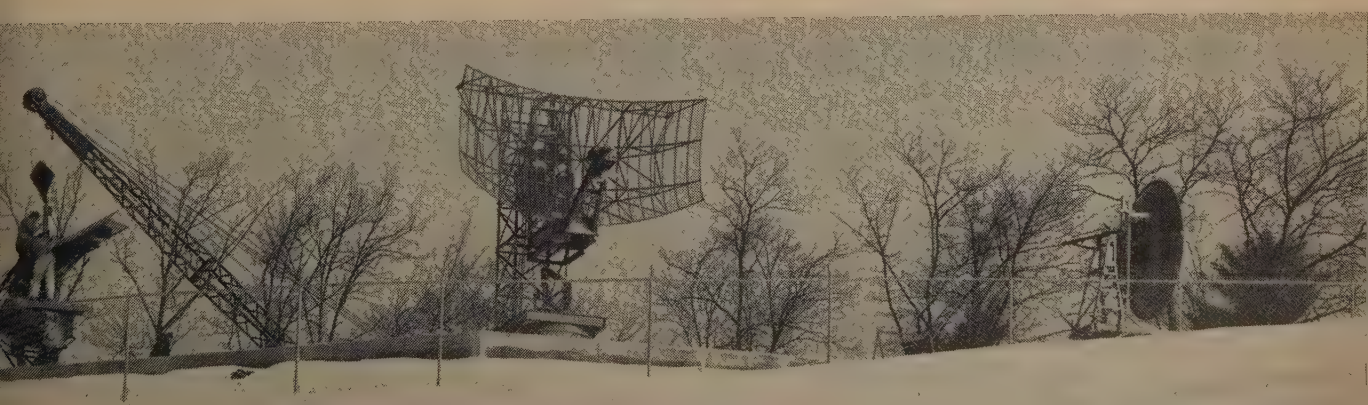
Corporate Structure

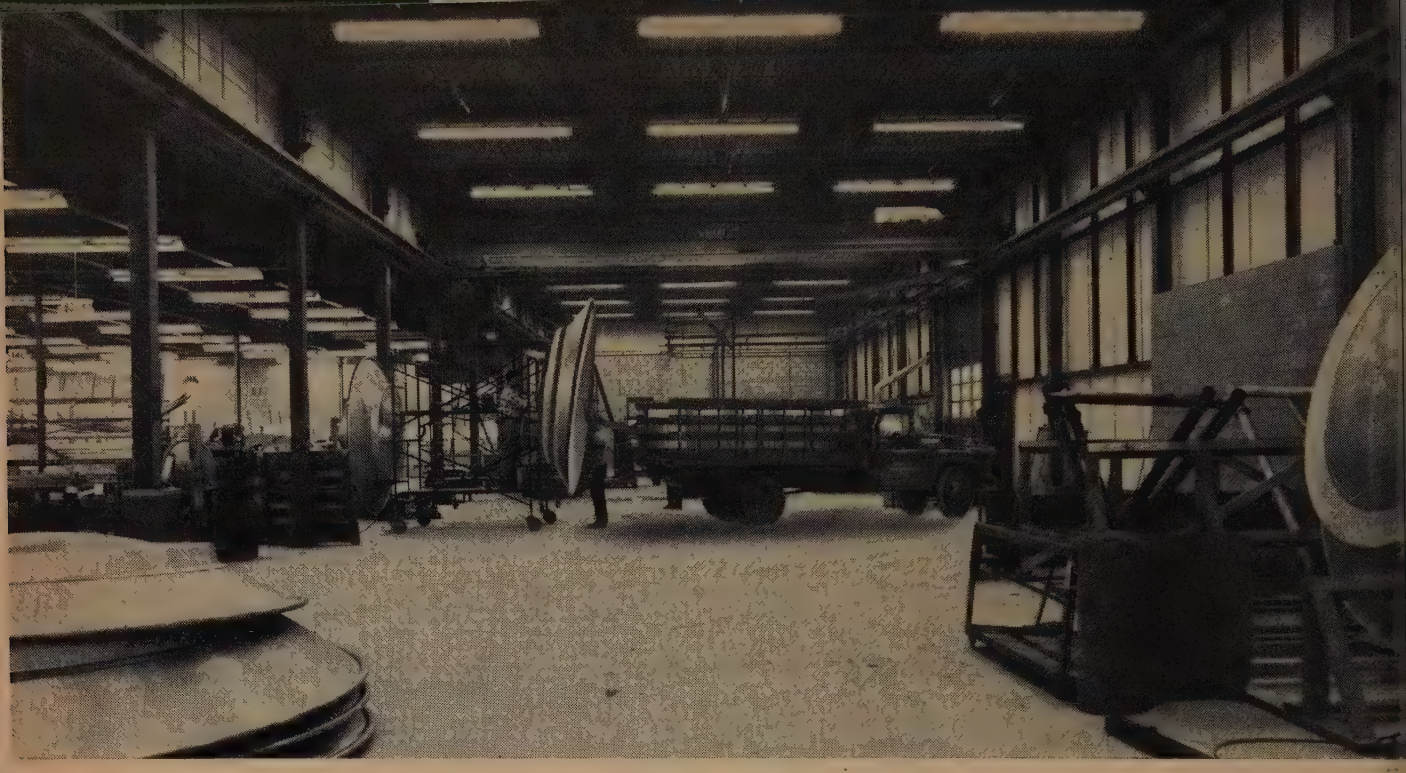
Gabriel Electronics is a Division of the Gabriel Company, headquarters, Cleveland, Ohio. The parent company, under John H. Briggs, President, is the largest independent manufacturer of automotive shock absorbers in the world. Further diversification is represented by an integrated operation, Rocket Power, Talco. This group operates a research center in Pasadena, California, concentrating on high energy fuel polymers, metal hydrides, and oxydizer materials of high energy content, as well as advanced propulsion systems and has manufacturing facilities in Mesa, Arizona. Another division is the Bohannon Manufacturing Division, of Compton, California, manufacturers of cartridge-actuated racks for force ejection of bombs, wing rockets, missiles and wing tanks for supersonic aircraft and missiles.

Personnel

The new management group at Gabriel Electronics Division is headed by Stanton L. Yarbrough, President and General Manager who received his B.S. in Engineering at the University of Southern California. He has been in electronics engineering over 20 years. Prior to coming to

Test range in winter.





View of the High Bay Area at the new Millis plant.

Gabriel, he was assistant to the Vice President of Manufacturing at Remington-Rand and directly concerned with the manufacture of large digital computers. Yarbrough also served in various executive capacities with several other leading corporations, including the Philco Corporation and the Rheem Manufacturing Company.

John B. Suomala, Vice President of Engineering, is a graduate of St. Louis University's school of Aeronautical Engineering, and has had 15 years of experience in engineering antenna systems and components. He has held line and staff positions with manufacturers of antennas, including the Bendix Aviation Corporation and D. S. Kennedy. At M.I.T.'s Lincoln Laboratories and Instrumentation Laboratory, for five years, Mr. Suomala's experience included inertial guidance systems in connection with ICBM and various large antenna systems.

James R. Wescott has been appointed to the newly created position of Vice-President of Marketing. He comes to Gabriel from General Electric's Heavy Military Division where for five years as Marketing Manager he was directly concerned with U.S. Army military systems and components procurement. Mr. Wescott has twenty years' experience in engineering design and management. He has an EE Degree from the University of Pennsylvania and is a member of the IRE and AIEE.

Gabriel's Director of Research, Dr. Allan A. Jayne, received a B.S. degree in Electrical Engineering from M.I.T. and a Ph.D. degree in Applied Physics from Harvard University. At M.I.T.'s Research Laboratory of Electronics, Dr. Jayne did research in antennas and microwave devices. At Gabriel, Dr. Jayne is responsible for the development of specialized antennas for military and commercial applications. Instrumental in many new developments in the field of telemetry and beacon antennas for large and small ICBM type missiles with his basic work in cavity-backed slots and flush mounted airborne antennas, Dr. Jayne has also developed high gain omnidirectional arrays with hemispherical coverage for missile ground-support command equipment and multi channel rotary couplers for aircraft radars.

Director of Sales, John B. Hamre directs departmenta operations in liaison with engineering and manufacturin departments. He has broad responsibilities for advertis ing and the analysis and evaluation of sales markets fo all of this division's products. Jack graduated from Middle bury College and is a member of IRE, ISA and Nationa Sales Executives.

Mr. Robert F. Stewart, Product Manager of Commer cial Microwave is a graduate of Worcester Polytechni Institute School of Engineering and Babson Institute o Business Administration. Mr. Stewart, with over te years' experience in the microwave field, is responsible fo the coordination of all programs supporting commercia microwave products. This includes marketing, sales, ad vertising, engineering, research and development, manu facturing, materials, and methods and packaging.

Bruno J. Pawlowski holds the position of Engineerin Marketing Manager. Mr. Pawlowski's 19-year back ground in antenna design, and his knowledge of and con tact with antenna programs in the military and industr made him extremely well-qualified for this position. H received his engineering degree from Tufts University

The Engineering Department

Under Jack Suomala, engineering consists of twen engineers who have an average of ten-years' experience microwave development and manufacture. The Researc and Development emphasis is one which makes full u of the broad and varied backgrounds of its scientific sta not only in their primary field of antennas but also in th related fields of electronics, geometric optics, serv mechanisms, hydraulic vibration, plastics, and electrom chanical devices. Gabriel feels that its future is insepar bly linked with its research and development progran It takes pride in the achievements which its enginee

e provided during the past five years. Among these the following: a twelve-month study on SHF passive ectors, (rectangular, elliptical and circular) and in- ation kits for the Signal Corps; high-temperature ma- ils study for re-entry telemetry and beacon antenna ipment for the Air Force; missile tracking helical ys, axially-driven devices, having high velocity track- and low tracking error for the Air Force; electronically rable d-f antenna study program for the Air Force; nd circularly-linearly polarized feed horn, remotely trolled, used to illuminate cosecant-squared reflectors n 2:1 aspect ratio and excellent ICR, for the FAA; and triple channel rotary joint with multi-type transi- is in unique configurations; X-band slotted array and porate structure for airborne feed systems using mono- se and cosecant-squared pattern, and single and dual nnel rotary couplers for ground and marine based enna systems, such as AN/FPS-7, AN/FPS-8. AN/ -30; AN/SPS-10, AN/SPS-11, AN/SPS-12, and many orne systems including AN/APS-62 and AN/APS-64. Gabriel engineers have investigated Cassegrainian feeds scatter and monopulse systems, new high-power feeds h dual frequencies and dual polarization for ultra-long ection, as well as new feeds and reflector designs for tems using parametric amplifiers and masers.

A study of the SHF passive reflector antenna system ond the conventional vertical radiation system was re- tly conducted for the Signal Corps. This 12-month dy involved the theoretical and empirical analysis of tem gains and sitings of flat rectangular, flat elliptical, l circular curved passive reflectors. The effects of vari- ons in the parameters involved in the siting of SHF sive reflector antennas were studied and experimentally stantiated in order to obtain specific performance cri- teria for the universal case where a single system may be employed in any possible configuration. Passive reflector studies are being continued on the side lobe effects of transmission at Ka band frequencies using a rectangular reflector.

Gabriel engineers have contributed many original ideas and ingenious techniques to the design of antenna components. A half dozen patents covering basic antenna inventions have been secured or are pending. Among these are a highly efficient broadband "Hopstretcher" feed used in microwave, high-power duplex horn feed systems for huge scatter-communication antennas, receiving and transmitting antennas for FM and TV broadcasting, municipal, commoncarrier, transportation and government services.

Manufacturing

The new facilities for manufacturing in Millis are ideally suited for production. The department can be scheduled and operated under better supervision and control than was possible in the four widely-separated facilities previously occupied by the manufacturing group.

John S. Hall, Manager of Manufacturing, has over 19 years experience in the electronics industry in mechanical design, production engineering, and administrative capacities. Prior to his employment here, Mr. Hall was Director of Manufacturing at American Standard Company and Chief Product Engineer on the Sparrow III at Raytheon's Lowell Missile System Division. Mr. Hall is responsible for manufacturing, manufacturing engineering, and material and production control. Under his direction, the production facility is now processing several medium size antenna production contracts; antenna components such as 6-foot rotary joints; various sizes of

Quality control — checking installation of four-point contact bearing in pedestal used on 19′ diameter antenna.

Seated, left to right are: John Suomala, Vice-President, Engineering; Stanton Yarbrough, President and General Manager; Jam Wescott, Vice-President, Marketing; Andre Castellano, Quality Control; Robert Stewart, Commercial Products Manager; Jo Hamre, Director of Sales; Charles Carlson, Personnel Director. Standing, L. to R., Dr. Allan A. Jayne, Director of Researc Edward Brown, Comptroller and John Hall, Manufacturing Manager.

airborne flush mounted antennas, and a sizable share of the point-to-point microwave parabolic antenna market.

The manufacturing department is staffed by a group of competent factory engineers under Fred Bell, who have greatly improved methods, cost control, and material control. As Chief Factory Engineer, Frederick P. Bell is responsible for estimating methods and cost control, tool design and control, and maintenance. He has had 20 years experience in all phases of production engineering.

The production control department is under Frank Jameson, who has over six years' experience in product scheduling and planning in the electronics industry.

This year the manufacturing department will produce twenty-five 18-foot ASR-4 antenna systems for Texas Instruments, Inc., Apparatus Division; thirty 28-foot ATCBI Beacon Interrogator antennas; over 100 5½ foot AT-781A/U circularly polarized omnidirectional drone control command antennas, and over one and one-half million dollars in point-to-point parabolic microwave antennas. In addition to these medium sized antenna contracts, Gabriel's production in rotary couplers for 1960 is expected to run over one-half million dollars.

Quality Control

Quality control is under Andre Castellano, who has an M.B.A. degree in Engineering Management, and 10 years' experience in electronics. This department is charged with maintaining a high standard of quality for products in an industry where reliability has become increasingly emphasized. Stress on quality control, Gabriel feels, has resulted in the company's being named sole supplier of 4000, 7000, and 11000 mc parabolic antennas for Western Electric's lines, and having been recently awarded a major contract through the systems manufacturer to supply all of the parabolic antennas on a point-to-point system that will cross the continent for a second utility.

Personnel Department

Charles Carlson, who has over 20 years' experience in this field, is Director of Personnel. Under his leadership, excellent recruiting and employee-management relationships exist because of a comprehensive personnel program which includes excellent working facilities, frin benefits, and a liberal education-tuition participation.

Product Line

Point-to-Point Communications Antennas. This is o of the company's oldest and most successful line of co plete antenna equipments. First developed after Wo War II by the company for the multitude of existing a potential uses, this class of antenna is referred to as t Public Utility Line, since it is supplied to common c riers. An example of common carriers is American Te phone and Telegraph who is supplied equipment throu Western Electric. This line is also supplied to indust and the government, where the approach to 100% " the air" performance justifies the ruggedized constructio Just now being introduced is Gabriel's new Commerci line of point-to-point antennas designed specifically f industrial application. A familiar sight along highwa and railroads, microwave communications systems ha been found importantly useful in forestry service, TV-S links and in increasing numbers of other industrial ser ices.

Through development efforts in providing superior a tennas, increased customer service, and reliability in pr duct and deliveries, Gabriel has been able to strengthe its position with the principal suppliers of microwave s tems equipment: Western Electric, Western Union, Ra theon, Motorola, Philco, RCA, Collins, and Lenkurt.

The company's microwave point-to-point activity, t year, will be increased by more than double 1959's volu which was more than twice the volume of any previo year.

Antenna Systems

Gabriel has produced medium size antennas, rangi between 15 and 45 feet for various shipborne and la based search and surveillance radar applications. In t shipborne class, Gabriel designed and developed t AN/SPA-21, Long Range Search Shipborne Radar A tenna, and produced over 300 of the AN/SPS-10, Lig weight Shipborne Search Radar Antennas.

In the Fixed Station Class, Gabriel designed and p

ed the HCD, Harbor Control Defense Antenna Sys-
consisting of a 30-foot reflector mounted on rugged,
ltiple-speed elevation pedestal, and the Sentinel, a high
ver long range radar antenna consisting of a 45 foot
g reflector mounted and rotated on a servocontrolled
estal.

or the Texas Instruments Incorporated, Apparatus Di-
on, Gabriel designed a completely new 19 foot re-
tor and a circularly polarized feed for the ASR-4
port Surveillance Radar Antenna.

he ATCBI, made for the FAA, is a linear, 28 foot
g, beacon array of 32 resonant cavities, radome covered
excited by stubs fed by a self-contained flat-strip
smission network.

o-space Antennas and Ground Support Antenna

tems

or military applications, Gabriel designed and made
AN/APS-62 Airborne Height-Finding Antenna con-
ing of a solid parabolic reflector, 2 x 6 feet, suspended
an aluminum fabricated structure, a horn feed system
a two axes drive mechanism. It is servocontrolled in
muth and elevation.

he GAM-63 Bell Rascal Antenna, a back-to-back, 60
h long radiator mounted in a hydraulically-driven, pre-
on pedestal which rotates the antenna at 350 rpm was
produced by Gabriel.

or North American Aviation's Autonetics Division,
company manufactured, tested, and installed a multi-
nnel waveguide feed system in the AN/APS-64 Air-
ne Radar Antenna.

Many omnidirectional antennas have been designed and
duced in quantity such as the UHF AT-782/U, a self
porting, 19 foot, mast antenna, with 10 bays of radi-
g elements located for null fill-in and overhead cov-
ge; the AT-781A/U which has four bays of radiating
ments and gives excellent circularized polarized cov-
ge for drone command operations; the AS-1051/FPS-35
F-UHF antenna, a 26 foot high stacked array of 36
izontally polarized UHF dipoles and 18 vertically
arized VHF dipoles fed by a flatstrip power divider.

ds and Horns

Gabriel has also produced tropospheric scatter antenna
nponents for systems serving the vital northern radar
tective screens (the DEW line, Mid-Canada, Pine-
, and White Alice systems), and dual polarized and
l frequency horns for ultra-long range radio-astronomy
ecting antennas. Many other advanced slotted arrays
corporate structures have been designed and developed
antenna systems from L to X bands. Recent develop-
nts include center-fed X-band duplex feeds and optical
l systems for monopulse operation.

ary Couplers

Rotary couplers for the following were designed: the
/FPS-7 Radar System, a part of the Sage system con-
s a rotary joint and a 100 circuit slip ring unit; the
Q-10A rotary joint, an X-band, broadbanded dual rotary
t, designed for high power; the 022 rotary joint, part
the Atlas launching system, is a combination dual
nnel r-f joint and multiple slip-ring assembly designed
olerate total submersion in water; the AIL dual channel
ry joint, recently built in quantity for Airborne Instru-
nts Labs; and a dual channel high power joint and
-ring assembly designed for Nike "B" installations.

Gabriel Electronics' new plant, seen from one of the test pads.

Financial and Future

The new facilities and intensive effort at Millis did not just happen by chance. When the new management team started on their growth program fifteen months ago, surveys made by independent sources and Gabriel's own management indicated that the microwave market was growing at an attractive rate. This, coupled with the expansion in military electronics in 1958 due to accelerated aero-space programs, as well as the natural growth in use of microwave point-to-point equipment, made it mandatory for the Company to anticipate this growth potential by capital investment for new facilities, and for improved management techniques.

A realistic evaluation of the microwave market indicates that the gross antenna sales for Gabriel's Electronics Division are increasing at better than 30% per year, and are expected to reach $14 million in 1963. This figure is felt to be conservative, based on the national figures taken from the Microwave Journal report on the "Fabulous Sixties," and the growth accomplished in the last fifteen month period in the new facilities.

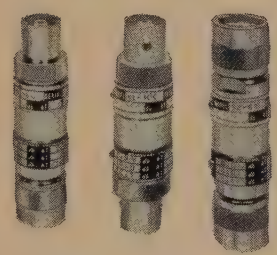
Speaking of the entire Gabriel complex, John H. Briggs, President, said, "Net earnings of the Company declined slightly during 1959, compared to 1958, while net sales increased 26%. Operating profit, however, increased 21% over the prior year. Net earnings in 1958 included a substantial capital gain from the sale of investment securities. During the year Gabriel completed major programs directed toward the acceleration of its long term growth, which has laid the groundwork for added profits over the next few years. In the past year, an International Division was established, two and a half million subordinated 15-year debentures were marketed, and bank financing was consolidated into a single $5,000,000 line of credit. This diversification and growth program should begin to contribute higher sales and profits in 1960, with the full effect being achieved in succeeding years."

WEINSCHEL
FIXED COAXIAL ATTENUATORS
Models 50, 51, 52
DC to 1 KMC, Usable to 2 KMC
Attenuation: 1 to 50 db
High stability, low frequency sensitivity
Finish: Stainless Steel (Type N Connectors); Nickel Plated (Type C or SC Connectors)

Type N Connectors

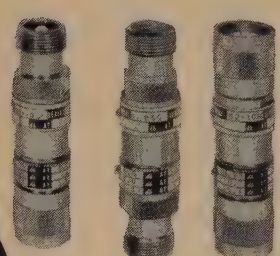
1 male 1 female | 2 female | 2 male

Type C Connectors



1 male 1 female | 2 female | 2 male

Type SC Connectors



1 male 1 female | 2 female | 2 male

Complete specifications upon request. Weinschel Fixed Coaxial Attenuators cover the frequency range of DC to 12.4 KMC. Write for complete catalog.

WE CO

Weinschel Engineering
KENSINGTON, MARYLAND

Circle Reader Service Card 35

New Products

(*Continued from page 60*)

NEW ECONOMY SWEPT MICROWAVE OSCILLATOR

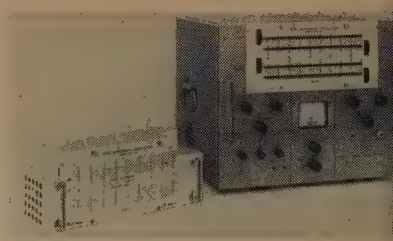
A new General Frequency Microwave Oscillator, featuring an oscillator with plug-in Generator Heads, has been developed by Alfred Electronics, Palo Alto, Calif.

Instead of buying a conventional oscillator which is limited to a single frequency range, the user can often save by purchasing Alfred's basic oscillator Model 605 and separate Generator Heads as needed.

Each Generator Head, consisting of a BWO tube and solenoid, inserts into a recess in the rear of the oscillator. Heads are available in standard steps of 1 to 2 kmc, 2 to 4 kmc, 4 to 8 kmc, 8 to 12.4 kmc, 6.5 to 11.5 kmc and 12.4 to 18 kmc. Heads are also available for 1.5 to 2.5 kmc and 10 to 15.5 kmc range.

The Model 605 costs $1,750. Heads vary from $1,590 to $1,990. Since one oscillator operates all Heads, the user saves $1,100 for each additional frequency range.

The sweep frequency of the Model 605 is continuously adjustable from 0 to band width extremes with an accurate Direct Reading Slide Rule Dial. "Quick



Look Readout" eliminates calculations setting sweep range.

Two adjustable frequency markers provided for rapid, broadband calib tion of an oscilloscope or recorder tr during observation of microwave co ponent characteristics. Internal squ wave modulation is available. Extrem low residual FM of ± .0025% and mi mum drift of ± .02% is obtain through the use of a current regula solenoid supply and regulated, tempe ture insensitive, low ripple electro supplies.

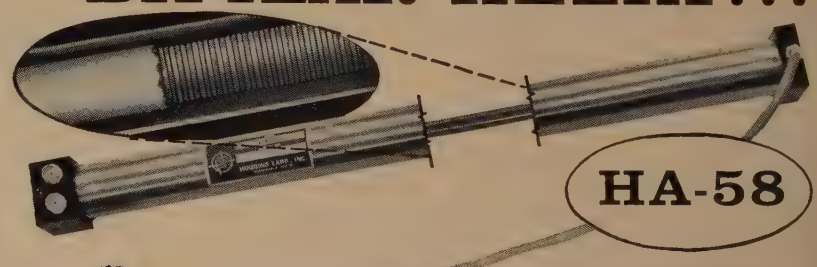
Circle Reader Service Card 106

—m w j—

ELECTRONIC PUMP FOR CLEA HIGH VACUUMS

Designed for systems requiring cle oil-free vacuums, a new high capac

THE TWT WITH A BIFILAR HELIX...



An Electrostatic focused 1 watt Traveling Wave Tube is t latest addition to the Huggins line of TWT's.

The HA 58 operates on a frequency range of 500 to 1000 MCS, with a small signal gain of 30 DB minimum, and a saturation gain of 28 DB minimum. Substantial savings in weight and size have been effected in this tube which measures 1¼" in diam ter and 18" in length. Weight is 1 lb. The tube is unusually rugged. magnetic structure either solenoid permanent magnet is needed by t HA 58.

Write for complete characteristics and prices.

HUGGINS LABORATORIES
manufacture
development
engineering
design
research

HUGGINS LABORATORIES INC.
999 East Arques Avenue Sunnyvale, California REgent 6-9330

Circle Reader Service Card 36

ltra-high vacuum pump with no mov-ng parts is now being offered by Ultek Corp., Palo Alto, Calif. The new pump ses neither fluids nor other contamin-nts and achieves a vacuum below x 10^{-9} mm Hg.

The pump, the UlteVac 327, achieves s vacuum by utilizing a cold-cathode ischarge in a magnetic field to remove as molecules and atoms from circulation y the formation of chemically stable ompounds and ion burial.

The pump is designed for long life nrough the use of compact, all metal ouplings with rotatable flanges, and ugged, utilized, internal structures to liminate virtual leaks. The pump is de-igned to draw current in a linear re-ationship with pressure, permitting it to ouble as a vacuum gauge.

The pump has applications in the elds of vacuum tube processing, semi-onductor processing, thin films and par-cle accelerators.

Additional information on the com-any's electronic vacuum pumps, sorp-ion devices, high vacuum fittings and igh vacuum valves can be obtained pon request.

Circle Reader Service Card 107

— m w j —

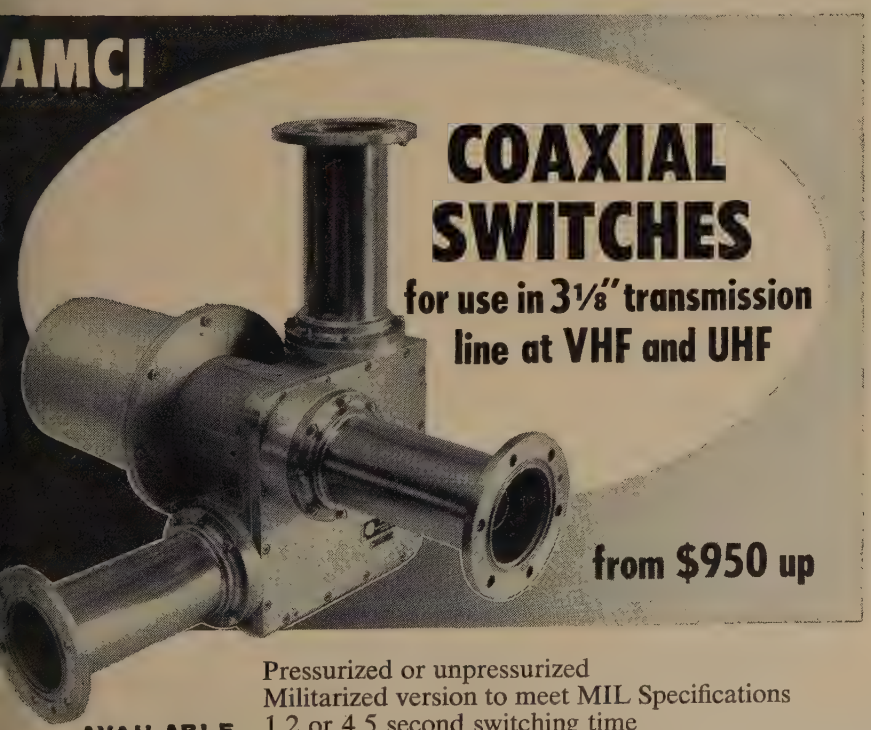
EXTENDED LINE OF HELIX ANTENNAS BY TACO

Technical Appliance Corporation, Sher-urne, N.Y., announce an extended line

of antennas and matching reflectors of the helix configuration. Current models include 4, 6, 8 and 10 turn types, of various sizes. Complete units, with reflectors, are made in single, dual and quadruple assemblies for mounting on manual or mechanized mounts. Taco helix antennas and arrays are available in all popular communications and telemetering frequency ranges. Polarization is circular, making them ideal for orbital body telemetering, or other airborne communications. Manual and remote controlled electro-mechanical mounts can be supplied. Complete details are available upon request.

Circle Reader Service Card 108

(*Continued on page 72*)



AVAILABLE FEATURES:

Pressurized or unpressurized
Militarized version to meet MIL Specifications
1.2 or 4.5 second switching time
High peak power handling capacity — ¾ megawatt at one atmosphere absolute pressure
Motor-driven or hand-operated

Write for complete information on AMCI Coaxial Switches

ANTENNA SYSTEMS COMPONENTS AIR NAVIGATION AIDS INSTRUMENTS
AMCI ALFORD Manufacturing Company
299 ATLANTIC AVE. BOSTON, MASS.

Circle Reader Service Card 37

NO. 1 OF A SERIES

Should a Specification Sheet Really Specify?

The answer to this question is not as obvious as it seems at first glance, if we were to base it on some of the specification sheets received here in the last few months.

There are several companies in our industry who seem to have abandoned the factual specification sheet, prepared by an engineer to communicate with other engineers. Instead they are releasing specification sheets that are obviously the product of extremely clever legal and advertising minds. Essential performance specifications are either omitted entirely or obscured by qualifying language. Skillful use of words enables the specification writer to skirt outright falsehood and deception, but still mislead all but the extremely wary.

We at Weinschel Engineering are disturbed to see "caveat emptor" become the ethical standard for even a small portion of the microwave industry. We like to make a sale just as much as the next fellow, so we employ advertising talent to make sure that our literature is attractive, well-organized and easy-to-read. However, our specifications are printed just as they are released by our engineering department and it is definitely "hands off" as far as the boys in the grey flannel suits are concerned.

Fortunately our major competitors seem to feel the same way we do and one of the joys of this business is making a sale against the type of competition offered by companies who try to beat our specifications in their research and development laboratories, not in their advertising or legal departments.

We suppose we should be philosophical and console ourselves with the knowledge that inevitably the company that misleads will fall by the wayside due to the difficulty of fooling the same people twice. But it pains us to see them get fooled the first time.

If you have any thoughts on this subject, we'd like to hear from you.

WEINSCHEL ENGINEERING CO
Specialists in Precision Microwave Calibration Equipment
Weinschel Engineering
KENSINGTON MARYLAND

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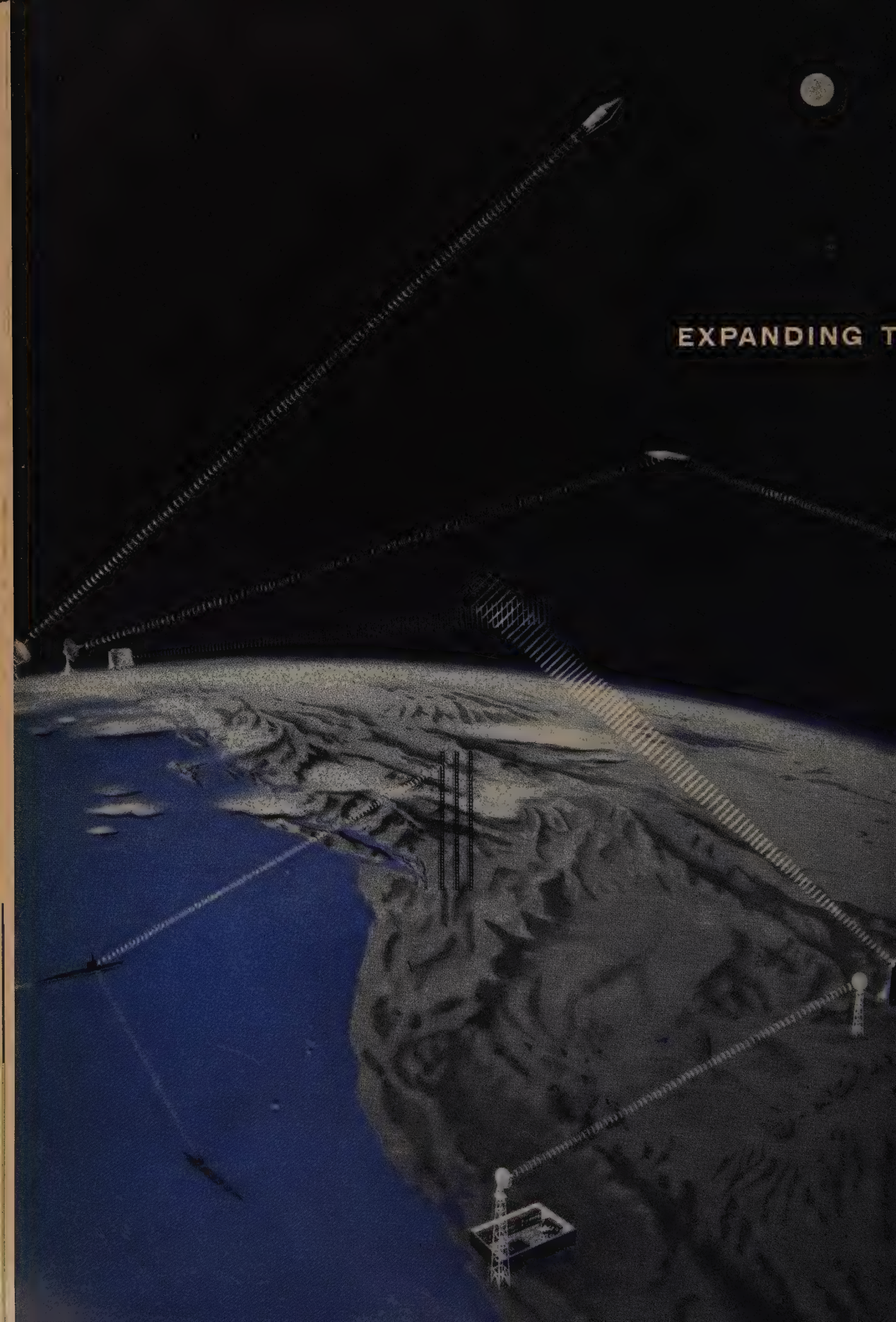

EXPANDING T

Herodotus, the historian, records (490 B.C.) the use of burnished shields for military signaling. This was the forerunner of the heliograph, invented by Sir Henry C. Mance, which came into wide use centuries later.

ONTIERS OF SPACE TECHNOLOGY IN

COMMUNICATIONS

Lockheed's interest in developing the science of communications extends from the depths of the oceans to deep space. Its Missiles and Space Division research programs deal with the development and application of statistical communication and decision theory in such areas as countermeasures; telemetry multiplexing and modulation; scatter communications; multiple vehicle tracking; millimeter wave generation and utilization; sonic signal detection and processing; avoidance of multipath degradation; and interference avoidance.

Associated research and development efforts are directed toward propagation studies and advanced antenna design; low noise amplifiers; vehicle borne signal transmission and reception, data storage and processing; solid state materials and devices.

The scope of such activities extends from advanced studies of naval communication problems on and under the oceans; the many applications to satellite vehicles; on to the specialized communication problems of deep space explorations. Latter needs are exemplified by high frequencies, low weight and power, high stability, low effective bandwidth, extreme reliability and basic simplicity requirements.

Engineers and Scientists: Investigating the entire spectrum of communications is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology — from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; communications; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space medicine; space navigation; and space physics.

If you are experienced in work related to any of the above areas, you are invited to inquire into the interesting programs being conducted and planned at Lockheed. Write: Research and Development Staff, Dept. F-27, 962 W. El Camino Real, Sunnyvale, Calif. U.S. citizenship or existing Department of Defense industrial security clearance required.

Lockheed / **MISSILES AND SPACE DIVISION**

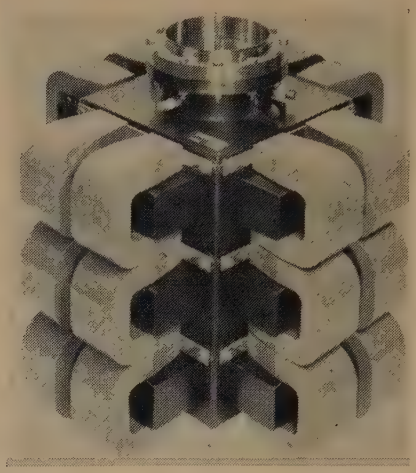
Systems Manager for the Navy POLARIS FBM;
the Air Force AGENA Satellite in the DISCOVERER,
MIDAS and SAMOS Programs; Air Force X-7; and Army KINGFISHER

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA
CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO • HAWAII

Circle Reader Service Card 39

(*Continued from page 69*)

HIGH-PRECISION 30 FOOT ANTENNA — MODEL 103



Antenna Systems, Inc., Hingham, Mass., has announced a new solid surface, high accuracy (±.065 to ±.125 surface tolerance), 30 foot paraboloid designed for wide use in the fields of radio astronomy, tropospheric scatter propagation, tracking radar and experimental test installations. A closer tolerance of ±.080 maximum is available on special order. Its fully machined sections guarantee interchangeability and easy assembly.

With an f/d ratio of 0.417, it ada readily to a wide variety of feed s tems, and the high surface accuracy p mits its use at frequencies above 10,(mc.

The feed support spars can be attacl to the perimeter of the dish, or to circle of supporting points four feet from the perimeter. A canti-levered lon support can be used, mounted the reflector frame and protrud through the surface at the vertex.

The antenna can be mounted on eit the top or side of a tower with azim and elevation adjustments, on el-az equatorial pedestals, self-contained tr er tower mounts, or other types mounts.

Circle Reader Service Card 109

—m w j—

FXR's NEW WAVEGUIDE SWITCHES

FXR, Inc., Woodside, N.Y., is p senting a new series of wavegu switches designed to be operated ma ally or driven electrically by a 28V solenoid actuator. Principle charac istics include broadband operation, VSWR, excellent isolation and high po er capacity. A milled aluminum ro

Antenna Systems, Inc., is devoted exclusively to the design, fabrication and installation of antenna systems in the fields of scatter communications, missile tracking, space tracking, radar and surveillance, radio astronomy, and special antenna products.

We invite your inquiry, whatever your antenna problem may be. Write for our folder.

ANTENNA SYSTEMS INC.
HINGHAM, MASS.

Circle Reader Service Card 58

ALL SIZES
MS FLANGES
IN STOCK

THE FINEST QUALITY BRASS AND ALUMINUM STANDARD WAVEGUIDE FLANGES in stock at Formcraft—all precision made to military standards. For rigid and flexible waveguides.

Special flanges to your specifications. Send sketch or blueprint for a quotation.

SEND FOR NEW BROCHURE #14B
DESCRIBING AND ILLUSTRATING ALL THE STOCK FLANGES

Formcraft TOOL CO.
2465 S. Archer Ave. • Chicago 16, Ill. • CAlumet 5-3173

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IF YOU DEPEND ON FERRITES ...YOU DEPEND ON IRVAN

from microwave to recording head frequencies, Irvan has a national reputation for superior performance. Irvan has the most complete and up-to-date facilities in the country for ultrasonic, surface, centerless, OD and ID grinding and has on hand over 30 grades of ferrite material for "yesterday" delivery on your ferrite orders.

IRVAN ENGINEERIN
13856 Saticoy Street Van Nuys, California
STate 1-2620

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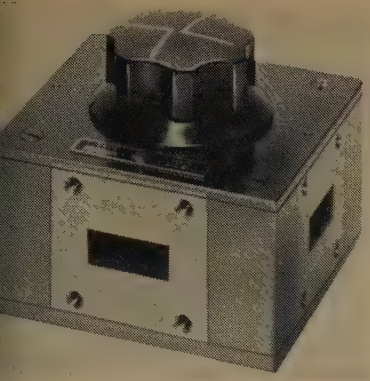


unted on precision ball bearings as-
e a long and trouble-free life.

The FXR Series 641 Waveguide
itches cover the frequency ranges from
5 to 40 kmc and each switch operates
er the full waveguide bandwidth. Max-
um VSWR is 1.10. The minimum
lation is 60 db for frequencies from
5 to 26.50 kmc and 50 db from 26.50
40 kmc.

Circle Reader Service Card 110

—mwj—

SYLVANIA HIGH FREQUENCY TUNNEL DIODES

Miniaturized tunnel diodes which offer
ctronic circuit engineers wider lati-
le in which to search out practical applications for the new tunneling phenomenon are in production at Sylvania Electric Products Inc., Waltham, Mass.

The new devices are capable of oscillating at frequencies in excess of 4,000 mc, four times the range of previously announced tunnel diodes.

Dr. William J. Pietenpol, vice president and general manager of Sylvania's Semiconductor Division, said the increased frequency range is the result of a unique etching process and a low inductance packaging technique.

Circle Reader Service Card 111

(*Continued on page 74*)

HI-POWER CALORIMETER BRIDGE

2% OR BETTER ACCURACY
COAXIAL or WAVEGUIDE

new!

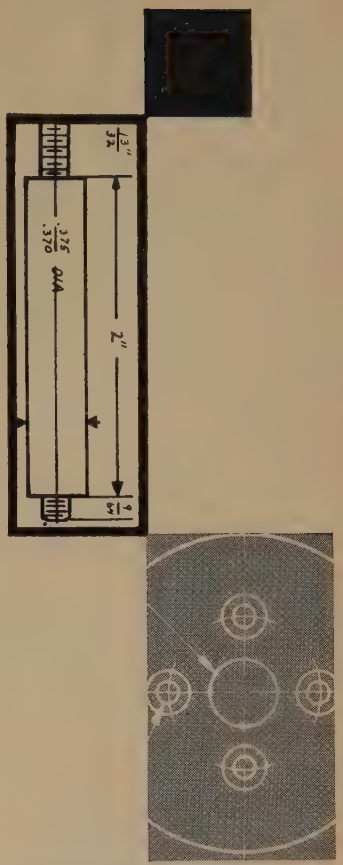
From 10 watts full scale to 5000 watts full scale.
Designed for continuous operation at 1000 watts.
Direct reading on all scales.
Simple operation.
All this in one self-contained package of 22" x 17" x 18".

In this Calorimeter Bridge the power dissipated in the R.F. Load is compared to the accurately metered AC power dissipated in a standard load resistor. Two thermopiles connected in opposition to each other indicate balance on a galvanometer. This Calorimeter Bridge is continuously self-calibrated electrically by a bridge-type circuit rather than by mechanical means.

- Provisions for external galvanometer and external wattmeter.
- Uses no thermometers, no flow meters.
- Self-compensating for wide changes in ambient temperature.
- Frequency range DC-12. KMC (Coaxial or Waveguide)
- Overall Accuracy 2%.
- Accuracy of internal wattmeter 1%.
- Completely self-contained with R.F. Load.
- Connector—1⅝".

WRITE FOR COMPLETE INFORMATION

Electro IMPULSE LABORATORY INC. | 206 RIVER ST. • RED BANK, N.J. Phone: SHadyside 1-0404



Product Development of

POLYIRON PERMEABLE DIELECTRIC

Attenuation UP TO 300 D.B. per inch

No other commercial dielectric can match POLYIRON'S numerous advantages:

- Easily molded or machined to any shape.
- Lower standing wave ratios therefore greater energy transfer.
- Relatively short terminations.
- Impedance data remarkably independent of wave lengths.

CUSTOM COMPONENTS Applications:

RF Gaskets, Waveguide Switches, Extending range of vane attenuators, Multi Conductor Filter Blocks, Terminations and Pads, Dummy Loads.

Deliveries co-ordinated with your needs. Special Shapes and Materials to fill your Specifications.

For details write or call:

CUSTOM COMPONENTS inc.

P.O. Box 248 Caldwell, N.J. • CApital 6-3404

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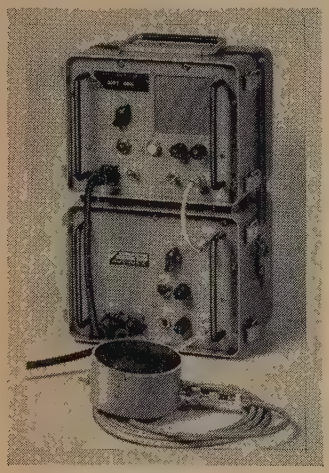
C.E.C. has for years been engaged in the design and production of quality components and systems for both military and industry. A member of our engineering group will be happy to meet with you on any microwave problems you now face.

MICROWAVE
COMPONENTS

ROTARY VANE FIXED ATTENUATORS

C.E.C. offers resistive attenuators that cover an entire waveguide band. These attenuators maintain a flat attenuation charactertistic over their entire waveguide band. ATTENUATION: 3 db, 10 db or 20 db are offered as Standard. Other attenuation values can be preset to your specifications.

INSTRUMENTS



VHF-UHF FREQUENCY CALIBRATOR MODEL 121

Range: 50 mc to 11,000 mc in crystal controlled steps of 50 or 100 mc.

Output Level: In excess of —70 dbm minimum for all markers.

Accuracy: ±0.005% at any frequency, unaffected by temperature or power input variations.

HARMONIC MULTIPLIER AMPLIFIER ADAPTER

Output Waveform: CW or Pulse.

Output Level: increases amplitude to —30 dbm in frequency range from 1,000 to 11,200 mc with marker spacing of 1,600 mc. Lower amplitude (—60 dbm) markers are generated with a spacing of 400 mc.

BROADBAND ANTENNA

Designed for use with the Harmonic Adapter, this broadband antenna covers the entire range from 1,000 mc through 11,200 mc.

Used in combination, the three units provide a fast go-no go, remote calibration check on aircraft radar receivers, without the need for connecting cables to the aircraft.

CONTROL ELECTRONICS CO., INC.
Ten Stepar Place, Huntington Station, N.Y.

New Products

(*Continued from page 73*)

KLYSTRON TUBE MOUNTS

A new line of klystron tube mounts is announced by DeMornay-Bonardi, Pasadena, Calif. Units provide a convenient means of coupling the output of a small reflex klystron to a standard size waveguide.

These tube mounts are fully pressurized, allowing direct connection to a pressurized system. Cover can be opened to change the tube without affecting waveguide pressurization. Tuning is stable regardless of pressure variations in the system.

The design provides for excellent RF shielding by means of (1) beryllium copper spring fingers which form an electrical seal between the body of the t mount and cover, and (2) filtering of input connector by the use of a spe absorbing material placed around the put leads. The design also includes cient heat dissipation and a multi-t dial on the tuning shaft for accurate quency resetability.

Designated as DB-111, these units insulation-tested at 1500 V peak. shell of the klystron is insulated fr the metallic parts of the mount so t unit can be run at a positive poten if so required by the AFC circuit, the operator is protected from high v ages on the klystron shell.

Units are available with vari mounting arrangements. Five sizes commodate tubes in the frequencies ra ing from 2.6 to 9.6 kmc. Prices ra from $237.00 to $315.00, depending size and configuration, and deliveries made in 30 days.

Circle Reader Service Card 112

—m w j—

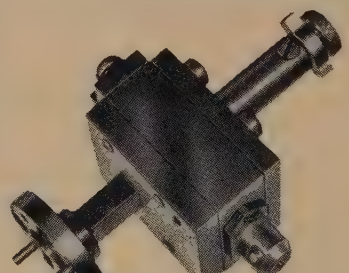
(*Continued on page 77*)

reaching out with TRG
INCORPORATED

MICROWAVE HARDWARE 30-140 KMC

Available for 60-75 KMC from stock or to your specifications.

EXCLUSIVE



CRYSTAL HOLDER FOR 4-MILLIMETER BAND

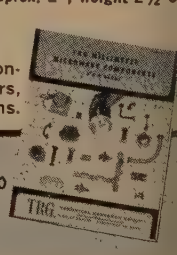
Available for mixing, detection or frequency multiplication in the 4-millimeter-wave band the new Model V-CH1 accepts a Philco IN2792 crystal, and incorporates a single tuning adjustment.

SPECIFICATIONS:

VSWR when matched:
< 2 for all crystals
< 1.5 for selected crystals

(Crystal not supplied)
Pressurization up to 30 P.S.I.
Length approx. 2", weight 2½ o

WRITE FOR NEW CATALOG 160A for details on Ferrite Components, TE_{01} Mode Circular Waveguide Components, Hybrid Mixers, Crystal Holders, Feed Horns, Dishes, Electroformed Transitions.



TRG INCORPORATED
ANTENNA & MICROWAVE DEPT.
9 Union Square, Somerville 43, Mass. • MOnument 6-8680
TECHNICAL RESEARCH GROUP
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Exclusively from Polarad...

CALIBRATED MICROWAVE FIELD INTENSITY RECEIVER SYSTEM

1000 to 10,000 mc

Model FIM being used to check radiated interference against MIL-I-26600

Determines absolute level of radiation, leakage and interference by comparison with an internally generated CW signal. Also measures signal susceptibility

...plete integrated Model FIM includes:

...monitoring unit. Meter indicates average, peak ... quasi-peak value of r-f signals. Outputs for ...leo, audio and recorder.

...F Plug In Tuning Units. Four units cover the ...equency range 1000 to 10,000 mc. UNI-DIAL ...ning control tunes both the receiver and ...ternal signal calibrator.

...librated Antenna System complete with tripod ...d a calibrated omni-directional Broadband ...tenna or a separate directional antenna to ...tch each R-F tuning unit.

...e this precision instrument for antenna pattern ...d shielding analysis, r-f power and voltage meas-...ements, determination of field intensity, signal ...opagation patterns and other microwave ...rameters.

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MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements."

...OLARAD ...LECTRONICS ...ORPORATION

...20 34th Street, Long Island City 1, N. Y. © P.E.C.

...resentatives in principal cities.

WM

POLARAD ELECTRONICS CORPORATION:

Please send me information and specifications on:

- ☐ Model FIM Calibrated Microwave Field Intensity Receiver
- ☐ Model N-1 Precision Noise Generator (see reverse side of page)

POLARAD

My application is_____

Name_____

Title_____ Dept._____

Company_____

Address_____

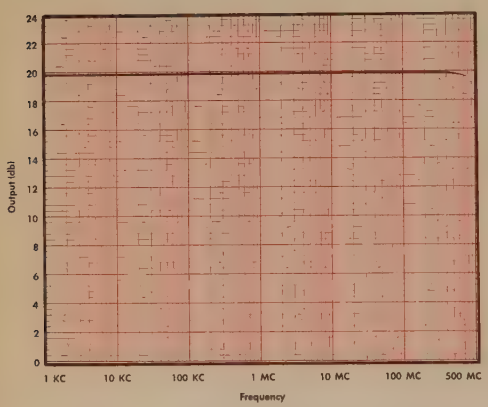
City_____ Zone_____ State_____

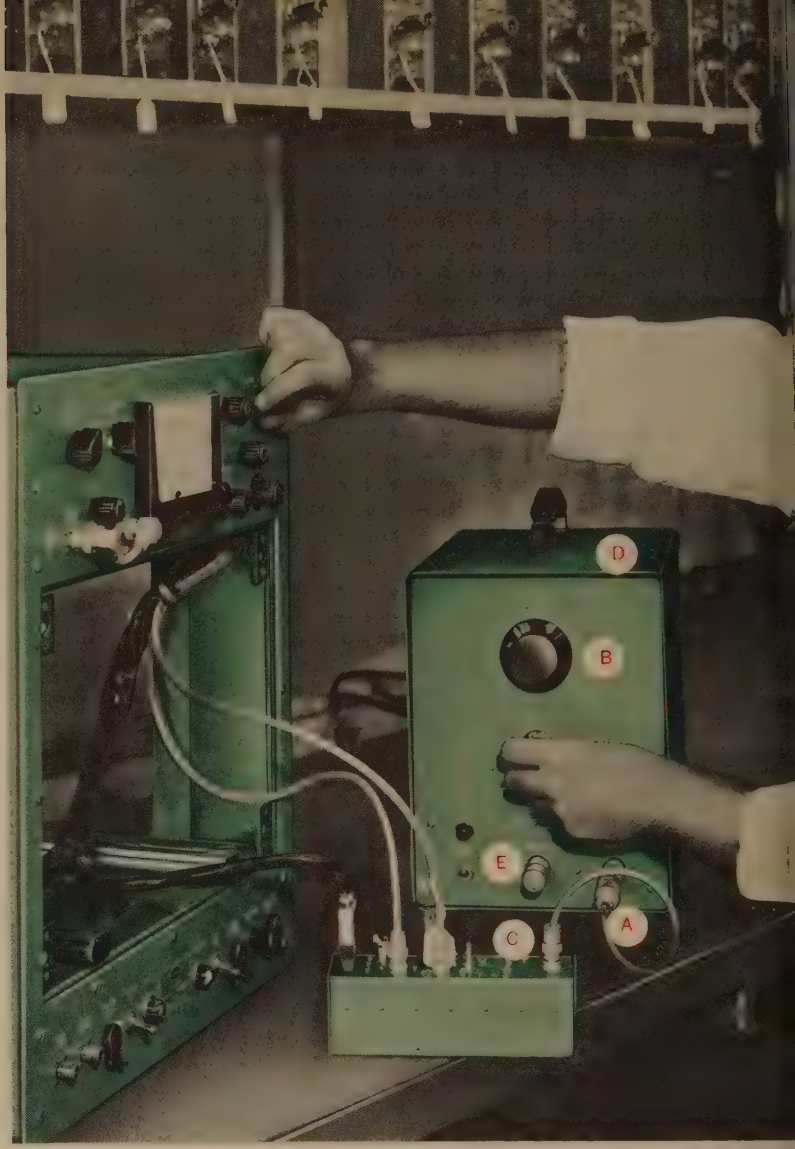
New from Polarad...

PRECISION NOISE GENERATOR

- **A** 1 kc to 500 mc
- **B** 1 to 20 db, adjustable
- **C** 0.25 db output accuracy
- **D** Long-life, low-maintenance noise tubes
- **E** Stable output

Noise output constant over entire frequency range. Maintains set level into any terminating impedance, 50 to 10,000 ohms.





Production line noise figure measurements, made rapidly and accurately with Polarad Model N-1.

The Polarad Model N-1 is a small, compact, portable noise generator with easy-to-operate controls. The Model N-1 (Digitized variable output level controls — 0 to 20 db. Calibrated 1 db steps — fine vernier between each step.) is entirely self-contained, including power supplies. Use it for direct noise figure measurements of vacuum tube or transistor amplifiers, receivers and oscillators.

Postage Will be Paid by Addressee

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v Products

(*Continued from page 74*)

CROWAVE MIXER ASSEMBLY

EL, Inc., Copiague, N.Y., offers the C-2 which further extends the range LEL's matched microwave receiver r-preamplifier units to cover the to 5.85 kmc bands. The MMC-2 has F center frequency of 30 or 60 mc, a mum gain of 25 db and an overall e figure of less than 7.5 db. Overall nting space needed is no greater that required for the mixer unit e.

cle Reader Service Card 122

—m w j—

EARFOTT OFFERS FIVE NEW AXIAL BROADBAND FERRITE ISOLATORS

ve new Coaxial Broadband Ferrite ıtors featuring very high isolation nsertion characteristics are now be- marketed by Kearfott Division, Gen- Precision Inc., Van Nuys, Calif.

ch of the new models covers one of popular bands — thus, the five units complete coverage of the major widths. Each model consists of co- construction with permanent mag- transverse field and ferrite sections into the unit. New materials and ufacturing techniques provide reduc- nsertion loss and increased power city. The connectors used on the tors are Type "N" Female Coaxial. e can be changed to fit customer re- ments.

cle Reader Service Card 123

GALLIUM SINGLE CRYSTALS PRODUCED BY MICROWAVE CHEMICALS LAB

Gallium Substituted Yttrium Iron Garnet Single Crystals are now being commercially produced by Microwave Chemicals Laboratory, Inc., New York, N.Y., according to an announcement issued by Richard Bell, sales manager. These single crystals are expected to find application in the low frequencies of the microwave region.

Two single crystal types are now available. One type has a saturation magnetization of 1000 gauss/cc while the other has 600 gauss/cc. The Curie temperature being 206 ± 2°C and 160°C, respectively. Both types have a narrow linewidth of not more than one oersted at C Band.

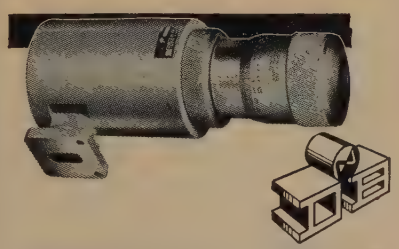
Several possible immediate applications are in magnetically tunable microwave filters, passive microwave power limiters and 3 level traveling wave masers.

Additional data on these products as well as specifications, sizes and availability of materials on other products can be obtained upon request.

Circle Reader Service Card 124

—m w j—

(*Continued on page 78*)



BROAD BAND CAVITY WAVEMETERS

—gas filled for sustained accuracy

Accuracy is so high these instruments may be used as secondary standards. Units are unaffected by changes in humidity, altitude or barometric pressure. Only 12 sizes serve from 2.6 KMC to 140 KMC. You save budget money on the number of sizes needed. Literature on request.

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DE MORNAY–BONARDI

780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

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NEW

DESIGN

COAXIAL

***LATCHING**

SWITCH

*** No Holding Power — Solenoid Actuated**

Meets extreme ballistic missile environment

SPECIFICATIONS

IMPEDANCE	50 ohms
VSWR	1.4
INSERTION LOSS	.4 db
CROSSTALK	30 db
WEIGHT	8.7 oz.

● also new from TRANSCO Waveguide Transfer Switch

SEND FOR COMPLETE PRODUCT DATA

TRANSCO

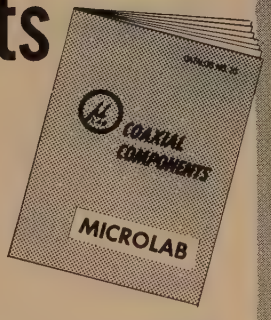
PRODUCTS INC.

12210 NEBRASKA AVE.

LOS ANGELES 25, CALIF.

Circle Reader Service Card 47

New Microwave Component Catalog Lists 7317 Stock Units



You'll want a copy of the new Microlab 72 page Microwave Component Catalog which includes newly designed **TERMINATIONS, FIXED** and **TURRET ATTENUATORS** (miniaturized, up to 12,000 mc; and high power, up to 15w; precision units with improved VSWR and attenuation values); **HIGH** and **LOW PASS FILTERS; COAXIAL TUNERS; RESISTIVE** and **REACTIVE POWER DIVIDERS; COAXIAL CONNECTORS; CRYSTAL MOUNTS; MONITOR TEES; DC BLOCKS; DC SHORTS; SIGNAL SAMPLERS.**

Catalog also includes **Design Section** for each product and a special article on the **Application of Matrix Algebra to the Design of Microwave Networks.**

WRITE FOR YOUR CATALOG NOW.

MICROLAB

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LIVINGSTON, N. J.
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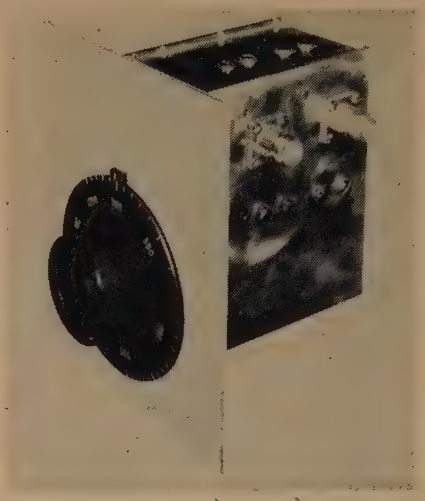
CAVITY BAND-PASS FILTERS MAY BE TUNED OVER 2:1 FREQUENCY RANGE



Multi-section, tunable band-pass filters have been developed by Telonic Engineering Corp., Laguna Beach, Calif., for use in applications where variable band-pass characteristics are required in the 250 to 2500 mc range.

The new Telonic TCF Cavity Filters are available in a series of cavity sizes. Insertion losses range from .5 to 3 db, depending on the number of cavities, which generally range from 2 to 9.

The Telonic filters are particularly suited to laboratory use. Power rating for the units is 100 watts. This, plus tunable feature, makes them ideal such applications as the selection or pression of harmonic frequencies in output of variable-frequency oscilla At the same time, the small size rugged construction of the units m them applicable to commercial and m tary RF systems.

Each cavity in the TCF filters con of a quarter wave stub, tuned by vari capacity loading. Tracking of the tions is accomplished by mechan links machined to close tolerances. S auxiliary capacitors aid in the track and permit band-pass characteristics t held within 5% over the tuning rang

Inductive loops are used for the put, interstage and output coupling. size, shape and position of these l are factory adjusted to obtain the sired band-pass characteristics. B widths from 1.5 to 20% are availa with channel rejection. Bandwidth pends on both the number of t cavities and the degree of coupling.

Input and output impedances normally adjusted for 50 ohms. VS is less than 1.5 to 1. Standard mo cover the ranges 250-500 mc, 500- mc, 1000-2000 mc and 2000-2500 mc calibrated dial indicates the center quency of the band-pass response. nectors are normally BNC. TNC Type N are also available.

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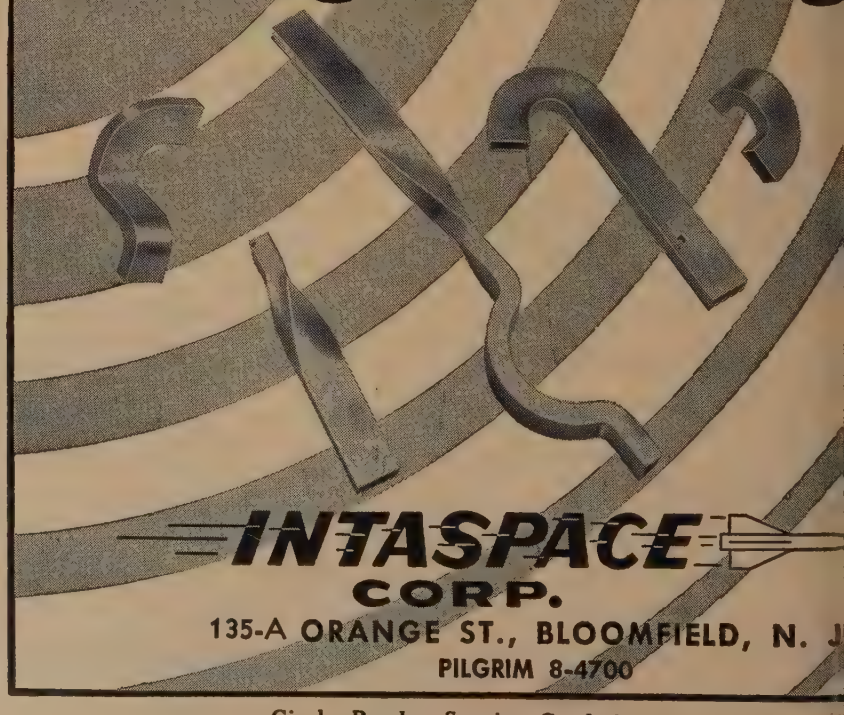
Waveguide specialists in close tolerance Bending and Forming



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SENIOR ENGINEER

FERRITE DEVICES

Opportunity for engineer well grounded in the interaction of microwave energy with ferrites to direct a creative device program. This is a position for a man who can handle responsibility for research and product line development.

The major direction of the program will be in the area of high power duplexers and other ferrite devices. Unusually excellent high power instrumentation is available for the investigation of phenomena over a wide frequency spectrum — 500 mc to 35,000 mc. The entire program is backed by an aggressive, competent technical staff capable of translating new ideas into practical devices.

Unique opportunities exist for professional and financial growth.

Please phone collect or send resume in confidence to:

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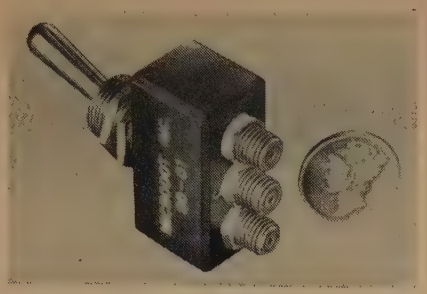
Telephone: Browning 2-3000

MINIATURE COAXIAL SWITCH



Microdot, Inc., South Pasadena, Calif., has announced the development of a miniaturized coaxial SPDT switch with all the electrical and mechanical features of normal coaxial switches. The new type 90-01 SPDT coaxial switch for 50 ohm cable is designed so that it can be directly inserted into a miniaturized circuit without adapters. Positive toggle action assures proper switching action and panel mounting provides easy installation. Mating connectors are available for application at, above, or below 400 mc.

VSWR is less than 1.2 to 2 kmc and insertion loss is 0.5 db at 2.0 kmc. Voltage rating is at 1500 volts maximum (60 cps) and crosstalk is better than 60 db to 2.0 kmc. Operative life is at a minimum of 50,000 cycles. The switch weighs only one and a quarter ounces.

Technical bulletins are available on request.

Circle Reader Service Card 126

— m w j —

2½ INCH IATRON STORAGE CATHODE-RAY TUBE

The FW-211 Iatron, newest of a family of storage tubes available from ITT Laboratories, Fort Wayne, Ind., is the brightest, lightest and smallest of its type. Used as a panel-mounted radar or infrared indicator in aircraft, its fast writing and high deflection speed permits accurate and instantaneous presentations. A special ITT-developed coaxial electron gun system eliminates trapezoidal distortion of the scanning pattern. Other special features include full daylight viewing of electrical signals by image intensification and the ability to write, store and erase information at will. A display exceeding 4000 foot-lamberts brightness is obtained at a phosphor voltage of only 8.5 kv. The tube fits within standard case dimensions for a 2¾ inch dial instrument and meets all of the environmental requirements of MIL-E-5400.

Complete technical specifications and price information available on request.

Circle Reader Service Card 128

Microwave Cavities

TRIODE OSCILLATORS

C Band

S Band

Whether you require the use of S band or C band triode transmitter and receiver oscillators, or tunable filters, John Gombos Co., Inc. provides complete design, manufacture and test of these and all other types of microwave assemblies, including sub-systems.

John Gombos Co., Inc.
Webro Road, Clifton, New Jersey

MICROWAVE · MECHANICAL · GOMBOS · ELECTRO-MECHANICAL · ELECTRONIC SYSTEMS

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Descriptive Literature

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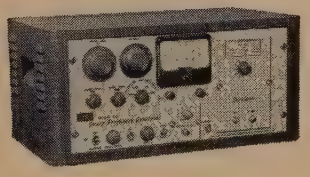
JERROLD

R. F. Test Equipment

Quantitative Measurements Using Sweep Frequency Techniques

Model 900A—THE MOST VERSATILE SWEEP GENERATOR $1,260.00

CENTER FREQUENCY—VHF 0.5 to 400 MC UHF 275 to 1000 MCS—**SWEEP WIDTH**—up to 400 MCS—**FLATNESS**—±0.5 db over widest sweep!



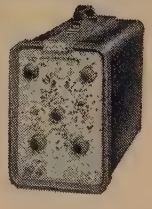
Model 707—ULTRA FLAT SWEEP GENERATOR $795.00

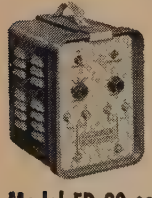
Featuring ±5/100 db flatness—Plug-in osc. heads*; variable sweep rates from 1/min. to 60/sec.; all electronic sweep fundamental frequencies; sweep width min. of 1% to 120% of C.F.

*Heads available within the spectrum 2 to 265 MCS

Models 601/602—PORTABLE GENERAL PURPOSE $295.00

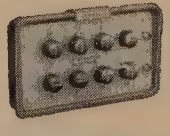
COVERAGE—Model 601—12 to 220 MCS. Model 602—4 to 112 MCS—**FLATNESS** — ±0.5 db **OUTPUT**—up to 2.5 V RMS **WIDTH**-1% to 120% of C.F.





Model FD-30 $250.00

High speed DPDT coaxial switch permitting oscilloscope measurements without calibration—all measurements referenced continuously against standard attenuators.



Model AV-50
Variable Precision Attenuator $150.00

Long life rotary switches; dual wiping silver contacts on "Kel-F" dielectric. 0-62.5 db in ½ db steps; DC to 500 MCS.

Write for catalog and technical Newsletter series on measurements using sweep frequency techniques. Prices and data subject to change without notice.

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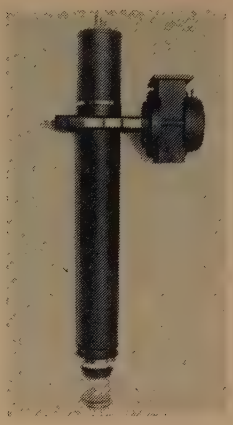
NEW BROADBAND KLYSTRON AMPLIFIER TUBE



A new Broadband Klystron Amplifier tube capable of providing over 2 megawatts of peak RF power with a 100 mc bandwidth at L-band has been added to the family of high power klystrons designed and manufactured by Litton Industries' Electron Tube Division, San Carlos, Calif.

Designated the L-3270 Klystron, this amplifier features flat band-pass and linear phase shift characteristics over the 100 mc bandwidth centered at 1300 mc as well as a minimum gain of 30 db. These achievements are the result of the recently developed "Skirtron" bunching technique originated by Litton Industries for improved broadband performance.

The characteristics of this new klystron tube make it suited for application as the output stage of sophisticated radar systems, particularly where frequency diversity or precisely shaped pulses are required.

Circle Reader Service Card 129

—*mwj*—

NEW KLYSTRON POWER AMPLIFIER

A new 2 kilowatt RF klystron power amplifier, designed for both military and industrial applications, has been developed by Sierra Electronic Corp., Menlo Park, Calif., a division of Philco Corporation.

Four VA-856 klystron tubes are used to give the Model 210A amplifier a range of 7.125 kmc to 8.5 kmc. It has a gain in excess of 40 db when operated as a broadband amplifier. Other versions of the Model 210A can be provided to cover the frequency ranges of 5.875 to 6.425 kmc or from 8.0 to 10.8 kmc. Typical applications include high power point-to-point communications, tropospheric scatter, and other microwave communications systems.

With the exception of the heat changer, all circuitry in the Model 2 is centralized in one cabinet with fr and rear access doors for easy servic All operating controls are on the fr panel for left-to-right operating quence.

Maximum bandwidths at the ½ po points are 15 mc, staggered tuned, 10 mc synchronously tuned.

The new amplifier is a sturdy, c pact unit weighing 1800 pounds measuring 84 inches high, 44½ in wide and 27 inches deep. The sepa heat exchanger weighs 500 pounds measures 33½ inches high, 25½ in wide and 42 inches deep.

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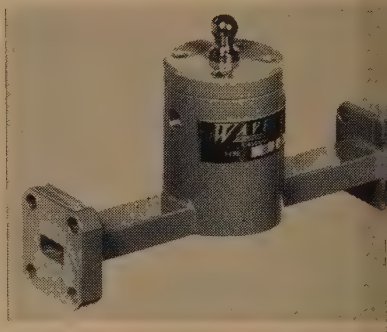
—*mwj*—

Ka BAND WAVEGUIDE SHORTI SWITCH



Waveline, Inc., Caldwell, N.J., nounces its new Model Number waveguide shorting switch. This un a hand operated plunger type or switch that provides a convenient m of establishing a removable short cuit in waveguide transmission syste

The switch has been designed to o ate over the frequency range of to 40 kmc with the following cha teristics: VSWR in the open positio 1.02 maximum and VSWR in the cl or short position of 125 minimum. sertion loss is negligible in the position.

The device is ruggedly constructe RG-96/U waveguide with UG-59 cover flanges and employs a pos action switching plunger to assure e ent performance. The unit has an all insertion length of three inches the maximum height of the unit the centerline of the guide to the to the plunger knob (in the withd position) is one and one half inche

A tight fitting plunger assembly i troduced into the waveguide section ing off the transmission system. fully withdrawn in the open positio continuity of the waveguide walls i tained and full operation with mini loss is retained.

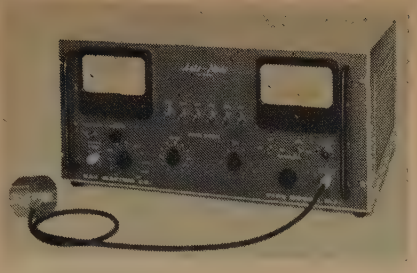
Circle Reader Service Card

NEW TEST EQUIPMENT FOR OISE FIGURE ADJUSTMENTS, D-OUTS AND MEASUREMENTS

ay Electric Company, Pine Brook, has announced the development of Kay Auto-Node, a complete, flexi- Automatic Noise-Figure Bridge. It esigned to obtain simplified, auto- c noise-figure meter displays for mak- optimum noise-figure adjustments and rovide precision noise-figure read-out, e-figure measurements using other external noise generators as well as ision measurements of Gain or Loss omponents and systems at microwave VHF frequencies.

he Kay Auto-Node features a small be size) temperature modulated re- r as a noise generator having the wing additional characteristics: Sine e temperature-modulation at a 10 rate with temperature excursions be- en 300° and 400° K; small VSWR ations during modulation (less than rts in 1000); useful frequency range oise generator from 2 to 2000 mc. resistor is easily replaced.

he Auto-Node's high-gain, low-noise amplifier has excellent noise-figure ility — better than 3.5 db (matched)



and the gain is sufficient to raise the input noise to a value of 10 volts after final detection. The bandwidth is 2 mc and the unit is supplied with one of three center frequencies (30, 60 or 70).

Precision, step attenuator and expanded output meter allows for measurements to within 0.2 db accuracy when making Gain or Loss measurements.

Bridge detection, selective AGC and synchronous detection allows noise figure up to 18 db to be made with small temperature modulation in the noise source.

Circle Reader Service Card 132

— m w j —

(*Continued on page 82*)

n't worry about losing Dr. Freebish — we're tracking his course on the radio telescope!"

Microwave Engineers:

OUTSTANDING OPPORTUNITY IN FLORIDA WITH VITRO

Vitro Weapons Services, a division of Vitro Laboratories, is expanding to operate the Microwave Program of the Eglin Gulf Test Range, which extends from Eglin Air Force Base to Key West, Florida.

This expansion creates a select opportunity for one experienced Microwave Systems Engineer to become Microwave Technical Advisor to the Range, reporting directly to the Department Manager, Technical Range Services. The man selected can ultimately achieve technical responsibility for the Range's entire Microwave Program. Applicants should possess B.S.E.E., and at least three years experience in Microwave Systems Engineering and Maintenance.

Vitro offers substantial employee benefits, including hospitalization plan, paid vacation, sick leave, educational assistance, retirement plan, excellent job security and merit system.

For your opportunity to advance your professional career with an industry leader in Florida, please mail a complete resume to:

Mr. Ed Drake
Personnel Director
Vitro Weapons Services
119 East Main Street
Fort Walton Beach, Florida
Dept. 18

All replies will be handled in confidence, and will receive prompt consideration.

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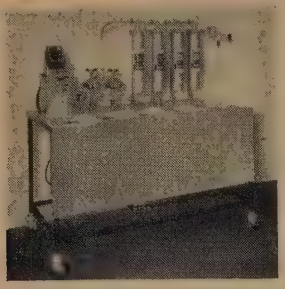
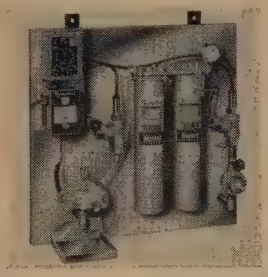
BARNSTEAD
PURE WATER
EQUIPMENT



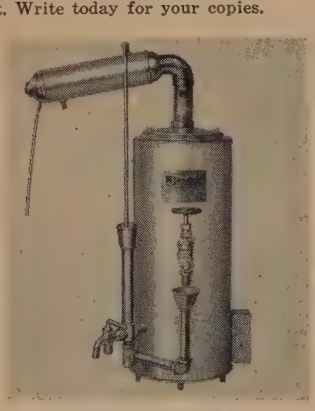
TRANSISTOR WASHER

Rinses transistors, diodes, and other small components in hot, ultra pure water. Built-in purification system continuously repurifies the water by (1) removal of organic impurities, (2) demineralization and (3) filtration of submicroscopic particles to 0.45 micron. RESULT: ultra pure final rinse water of 18,000,000 ohm electrical resistance and free of organic impurities and minute particulate matter. Available in several sizes. Ask for Bulletin No. 146 A.



COOLING WATER RE-PURIFYING SYSTEM

Adds thousands of hours to UHF Transmitting Tube life and saves additional hours of maintenance ordinarily spent in citric acid cleaning procedures within the cooling system. Bulletin 149 and Technical Bulletin 156 cover complete subject. Write today for your copies.



BARNSTEAD WATER STILLS

The most efficient way to obtain purest distilled water in either laboratory or production quantities. Over 200 models and sizes from ½ to 1000 g.p.h. Write for Catalog "H".

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Barnstead
STILL AND STERILIZER CO.
48 Lanesville Terrace, Boston 31, Mass.

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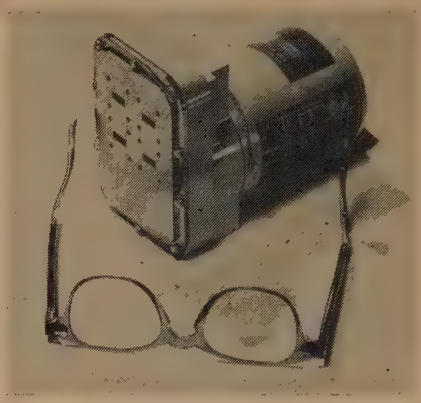
New Products

(*Continued from page 81*)

WAVEGUIDE TRANSFER SWITCH K AND X-BANDS



A newly designed K-band transfer switch has been placed in production by Transco Products, Inc., West Los Angeles, Calif.

Also available for X-Band, the switch can be operated as SPDT or double pole transfer. Both size and weight are minimum presently available for waveguide transfer switches.

Typical specifications of this 28 VDC motor actuated switch are: VSWR 1.05; Insertion loss .07 db; Crosstalk 80 db.

Circle Reader Service Card 133

—*m w j*—

BIFURCATED GOLD CONTACTS BOOST SWITCH RELIABILITY

Bifurcated gold contacts for increased switch reliability and stabilized contact resistance in data processing, radar and radio circuits are a feature of a new subminiature snap-action switch announced by Micro Switch, Freeport, Ill., division of Minneapolis-Honeywell Regulator Co.

Used in dry, (low-energy) circuits, these gold contacts offer low resistance with greater life and reliability characteristics in millivolt and milliampere circuits.

The bifurcated contacts (two contact surfaces in each position) move with a wiping action to clean the surfaces with every cycle.

Electrical rating of the single-pole double-throw switch is 5 amps at 30 volts dc. Switch weight is .006 pounds, operating force 3 to 5 ounces, dimensions ¼ by ⅛ by ¾ inch.

Circle Reader Service Card 134

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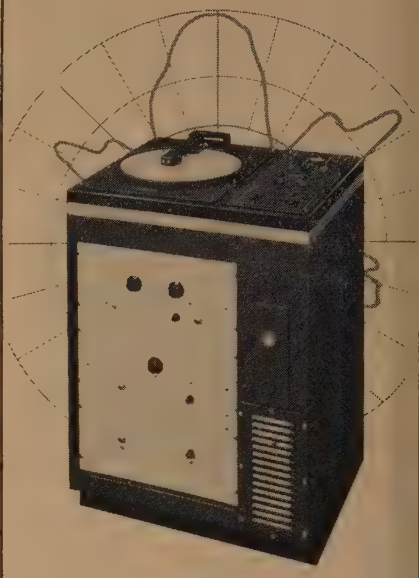
(*Continued on page 83*)

POLAR PATTERN RECORDING SYSTEM



Measures Antenna Radiation Patterns

AIL's Type 116R Polar Pattern recording system precisely records directional characteristics of electromagnetic, acoustic, thermal, atomic, and light radiation patterns. It traces, in polar coordinates, a continuous inked plot of input voltage vs angular position.

Precision performance is assured by low internal noise, high sensitivity, accurate turntable drive and exact pen response.

Available accessories include a new automatic relative power computer and a square root amplifier.

Price: $3100.00

Write for details.

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK
A DIVISION OF CUTLER-HAMMER, INC.

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(*Continued from page 82*)

MICROWAVE TRAINING UNIT DEVELOPED

Development of a Microwave Training it, designed to help bridge the gap ween the science classroom and the ustrial laboratory, has been announc- by the Airsupply-Aero Engineering vision of The Garrett Corporation, s Angeles, Calif.

The organization will handle sales for ma Electronics Research Corporation, veloper of the unit.

Serco's Microwave Training Unit is assembly of power source, transmis- n and receiving components. They ovide the basic stages of a complete crowave system and permit a com- hensive demonstration and analysis microwave theories and techniques.

The accompanying laboratory manual ntains detailed instructional aids and complete series of laboratory experi- nts, compiled by microwave engin- s possessing college and industrial ching experience.

As a research tool, the Microwave ining Unit is useful for studying the ational energy bands of gases, ra- ne characteristics, design of new-type ennas, characteristics of solid state vices, etc.

Included in microwave applications communications, radar, navigation, nter-measures, use as a research tool atomic and molecular structure de- tion, and demonstrating of optical physical wave phenomena.

The unit has value for the military, ustry, colleges and trade schools for ining electronic technicians in the damentals of microwave theory and asurements.

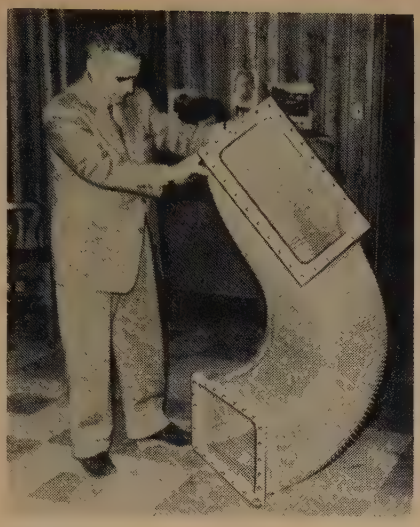
Circle Reader Service Card 135

—*mwj*—

BALANCED-PHASE FLEX-GUIDE FOR UHF WAVEGUIDE TRANSMISSION LINES

Balanced-Phase (B-ϕ) Flex-Guide, the t innovation in the flexible waveguide d in many years, was recently an- nced by E. M. T. Corporation, New- , N.J.

The new B-ϕ construction is essentially onvoluted flexible tube with two lap- axially seams, one on each broad veguide wall located diametrically posite each other, close to the side lls. Employing two seams, properly ated, minimizes the cross-section dis- tion associated with bending since the ealed seam is supported by the strong walls. In addition, the flexible tub- which is soldered or welded to ge fittings at the extremities is sup- ted at the corners (strongest parts



of the cross-section) by specially designed brackets, which preclude from flexing, the areas near the fitting that have been annealed during fabrication, thus improving the flex life of the assembly.

The following are some of the advantages that accrue from the use of EMT's B-ϕ Alumna-Flex assemblies:

1. Elimination of non-compatible materials. All-aluminum flex guide is available for use in aluminum transmission lines.

2. Elimination of fluxes at fittings. Fittings are Tungsten Inert Gas (TIG) welded to the flexible tubing.

3. Elimination of fluxes, plating and cleaning solution entrapment.

4. Improvement in the fatigue life of the flexible assembly, by
   a) Reduction of the tube anneal in the clamping area.
   b) Attaining of smaller bending radii by using a high convolution and small pitch in the flexible tubing.
   c) Minimizing physical irregularities by locating the annealed seam in an area where it is supported by the strong side walls.

5. Weight reduction. This facilitates field handling and installation.

6. Cost reduction by virtue of improved manufacturing techniques.

7. Field replacements are greatly minimized.

B-ϕ Flex-Guide assemblies are available either in preformed configurations or in straight lengths for bending in the field.

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—*mwj*—

(*Continued on page 84*)

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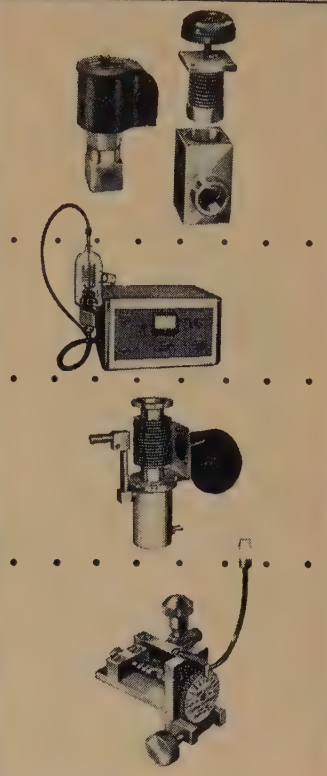
HIGH VACUUM COMPONENTS



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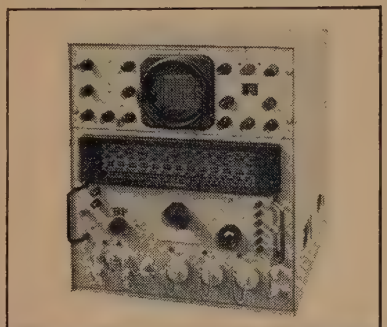
extreme sensitivity 10 mc to 44,000 mc



PANORAMIC'S
SPA-4
SPECTRUM
ANALYZER

MORE USEABLE SENSITIVITY

BAND	RF SENSITIVITY*
10 — 420 MC	—95 to —105 dbm
350 — 1000 MC	—90 to —100 dbm
910 — 2200 MC	—90 to —100 dbm
1980 — 4500 MC	—80 to — 90 dbm
4.5 — 10.88 KMC	—80 to — 95 dbm
10.88 — 18.0 KMC	—70 to — 90 dbm
18.0 — 26.4 KMC	—60 to — 85 dbm
26.4 — 44.0 KMC	—55 to — 85 dbm

*measured when signal and noise equal 2X noise

Using one tuning head which contains one triode and two Klystron oscillators, Model SPA-4 offers more exclusive advantages for applications demanding extreme sensitivity, stability, versatility, accuracy.

- **Three precisely calibrated amplitude scales—40 db log, 20 db linear, 10 db power.**
- **Two independent frequency dispersion ranges—continuously adjustable—0-70 mc and 0-5 mc. Negligible internal frequency modulation permits narrow band analysis of FM problems.**
- **Variable I.F. bandwidth from 1 kc to 80 kc.**
- **Push-button frequency selector.**
- **Synchroscope output with 40 db gain.**
- **Accurate measurement of small frequency differences. A self-contained marker oscillator, modulated by a calibrated external generator, provides accurate differential marker pips as close as 10 kc.**

Tremendous flexibility and many unique advances of Panoramic's compact SPA-4 make it unsurpassed for visually analyzing FM, AM and pulsed signal systems; instabilities of oscillators; noise spectra; detection of parasitics; studies of harmonic outputs; radar systems and other signal sources.

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OWens 9-4600
Cable: Panoramic, Mt. Vernon. N.Y. State

New Products

(*Continued from page 83*)

MOTOROLA ANNOUNCES FIRST COMPACT UHF ISOLATOR

The Motorola Solid State Electronics Department, Phoenix, Arizona, has announced the first commercially available compact, lightweight isolator designed for operation in the 440-470 mc band.

Designated Model LI 01, the new ferrite isolator covers a bandwidth of 30 mc centered at 455 mc and provides more than 10 db isolation with less than 1.0 db insertion loss, according to John C. Cacheris, microwave components laboratory manager.

The compact isolator measures only 3½ inches x 2½ inches x 1.0 inches including two BNC connectors, or less than the size of a package of cigarettes. It weighs approximately 8 ounces. In principle, the design characteristics are based on the work of Seidel of the Bell Telephone Laboratories, as reported in the April, 1959, Journal of Applied Physics.

The techniques which enable achievement of the small sizes are expected to be used for other Motorola isolators in the range 100 mc to 700 mc, Cacheris said.

Possible applications for the compact isolator include its use in the laboratory, in navigation, telemetry and satellite

tracking programs, and in fixed and bile communications systems. It can be used to advantage in optimiz the performance of parametric and nel diode amplifiers by stabilizing gain from changes in antenna impeda

The Model LI 01 UHF isolator available for delivery within 30 to days in production quantities. It is av able also at other UHF frequencies u special order.

Additional information and speci tions are available upon request.

Circle Reader Service Card

NEW LITERATURE

SHORT-FORM CATALOGS DESCRIBE MICROWAVE ASSOCIATES' PRODUCTS

Three new short-form catalogs describing the products of Microwave Associates, Inc., Burlington, Mass., are now available.

For convenience the short-form catalogs cover separately (specifications, photos) the products of Microwave Associates' three divisions: Semiconductor Products (microwave silicon diodes, varactors, and computer diodes), Microwave Components Division (waveguide components, test equipment and custom engineered microwave assemblies) and Microwave Tubes and Devices (duplexer tubes, magnetrons, ferrite devices, coaxial limiters, switches and complete duplexers).

Circle Reader Service Card 138

— m w j —

SYLVANIA ANNOUNCES NEW CATALOG ON FERRITE DEVICES

A new four page catalog on ferrite circulators and isolators has been made available by Sylvania Electric Products Inc.

The catalog lists electrical characteristics and over-all length for more than 60 models of coaxial isolators, broadband and special-purpose waveguide isolators, compact "Tee" circulators and phase-shift circulators.

One of the typical units described an octave S-band isolator capable of db isolation with 1 db insertion loss 1.2 VSWR.

The octave S-band isolator, develo more than a year ago, is one of the vices now being manufactured in la quantities on a production-line basis, cording to Thomas D. Fuller, market manager of Sylvania's Special Tube O ations.

Devices are available from 1 to kmc. Waveguide isolators and ph shift circulators capable of handling kilowatts peak power are also listed.

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— m w j —

BROCHURE AVAILABLE ON REFRIGERATION SYSTEMS FO CRYOGENIC ELECTRONICS

A variety of miniature and compact frigeration systems for cooling electr devices to temperatures ranging f 3.5°K to 200°K is described in a brochure published by Air Products, Allentown, Pa.

To meet the expanding needs of electronics industry for refrigera equipment to operate infrared detec masers, irasers, parametric amplifiers for transistor and superconductor a cations, Air Products has developed

nufactured a wide variety of matched
ponents for refrigeration systems.
erational systems are now available
airborne, land-based and laboratory
lications.

ir Products is a leader in the design,
nufacture and operation of low tem-
ture process plants and cryogenic
aratus for the electronic, chemical
steel industries and the government
ketry program.

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—*m w j*—

OSCILLOGRAPHY BOOKLET FFERED BY HEWLETT-PACKARD

An eight page Application Note en-
ed "Sampling Oscillography" is now
ilable from the Hewlett-Packard Co.,
o Alto, Calif. Sampling oscillography
a method for pulse analysis of ultra
circuits — as with transistors, diodes,
nory units, fast computer circuits, sur-
lance radars and other millimicrosec-
pulse applications.

his Application Note (#36) traces
history of the sampling technique and
recent application to oscilloscopes, ex-
ding their usefulness into a higher
tion of the frequency spectrum. It
discusses general sampling consider-
ns and describes the design and oper-
n of Hewlett-Packard's new Model
A sampling oscilloscope.

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—*m w j*—

ROLD OFFERS TEST EQUIPMENT CATALOG

fully-illustrated catalog "RF Test
ipment for Quantitive Measurements"
recently been published by Jerrold
tronics Corp., Philadelphia, Pa. The
page booklet describes the full line
Jerrold test equipment which is de-
ed for accurate RF measurements in
laboratory, production test facility or
field service.

eatured is an introduction to Jerrold
C (measurement by comparison) tech-
es. These techniques, made possible
ugh the use of the new Jerrold com-
tor, bring new speed and accuracy to
procedures. MBC eliminates the
for costly, time-consuming calibra-
"take downs." The MBC system is
inuously self-calibrating.

he new booklet describes measure-
t of amplifier gain, VSWR and equip-
t loss and offers illustrated examples
ach.

quipment descriptions included are of
p generators, marker generators,
parators, sweep frequency test sets,
e pre-amplifiers, RF attenuators, de-
rs, terminators and transfer switches.

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(*Continued on page 86*)

OPPORTUNITIES IN UHF AND MICROWAVE RESEARCH AND DEVELOPMENT

Never before has such high priority been given to microwave research and development . . . never before have the opportunities been so great in this field for the qualified engineer and scientist.

The Research Center of The Bendix Corporation—The RESEARCH LABORATORIES DIVISION—is expanding its programs in the UHF and microwave field to create interesting and challenging positions for qualified personnel.

Technical openings are now available in the following fields:

ANTENNA RESEARCH in electronic scanning, log periodic antennas, microwave optics.

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Investigate these opportunities *now*, where your technical competence and potentialities will receive full recognition in "Building Your Future with Bendix".

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Responsible for direction of regional sales force marketing products for four (4) components divisions, within key geographical areas. Openings in greater New York and Southern California. Requires personal selling and sales management experience. Minimum three (3) years successful selling of complex components.

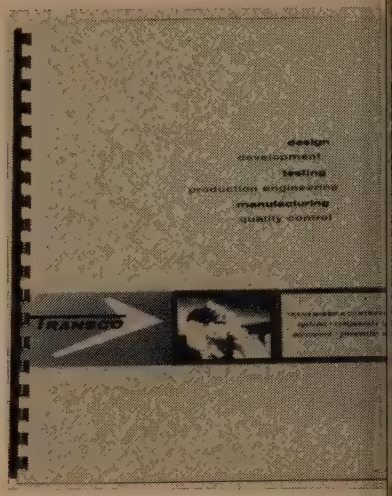
Send resumes to A. Wilkins, 200 E. Hanover Ave., Morris Plains, N. J.

LITTON INDUSTRIES

New Literature

(Continued from page 85)

TRANSCO RELEASES NEW MICROWAVE CATALOG



A new spiral bound, quick-refer Microwave Catalog has been annou by Transco Products, Inc., Los Ang Calif. The 26 page book covers company's line of microwave prod plus special charts and graphs for microwave engineer.

The sections of the catalog offer plete product information on micro switches, coaxial and waveguide; po dividers, directional couplers and c microwave components; Transco's m plex antenna systems; antennas and tenna systems. Also included is a cial Data Section devoted to a serie practical charts and graphs to aid microwave engineer.

Each product sheet offers com specifications, applications, options, mensional data, schematics and des tions chart.

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—mwj—

TRAK ELECTRONICS ANNOUN A NEW BOOKLET ON "MULTICOUPLER PERFORMAN

The new TRAK "Multicoupler formance" booklet discusses multicou characteristics, their measurement their effect on system performance. booklet includes a technical discus on: kinds of multicouplers, specif the multicoupler for a particular sy (noise figure, distortion, isolation, i tion gain and bandwidth, numbe output channels, input impedance VSWR, and interchange of Paramet and multicoupler testing (aspects testing a multicoupler, typical measu circuits, block diagram isolation block diagram distortion test, sche switch box for distortion test and b diagram noise test figure).

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—mwj—

SALES MANAGER

Continued growth and development in the microwave field has created an opening for an experienced microwave engineer to assume the responsibilities of Sales Manager. The position requires familiarity with the present state of the art and prior sales experience or ability.

In return we offer you professional freedom and integrity; scheduled salary reviews; complete employee benefits, including 100% tuition refund; and a secure, attractive future with one of the country's top three microwave instrument manufacturers.

Salary commensurate with the position — relocation expenses paid. Contact Mr. David Austin, Personnel Manager, in confidence.

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3 — A desire to work hard to earn a key professional position in rapidly growing organization.

4 — An outlook on life which requires you to do an excellent job even if your audience consists of just a few similar-minded specialists.

If you feel you meet these qualifications, write to:
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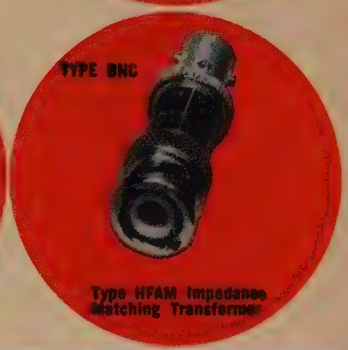
Coaxial Attenuators
Terminations
Impedance Transformers
DC to 2500 mcs.

using type BNC, TNC, and N coaxial connectors



ARI presents an integrated line of coaxial attenuators, terminations, and impedance matching transformers for use in the DC to 2500 mcs frequency range. To provide the user with a greater flexibility than heretofore realized, type BNC, TNC, and N coaxial connectors are incorporated in this family of attenuators and terminations. The impedance matching transformers use type BNC coaxial connectors.

The attenuators and terminations exhibit a nominal impedance of either 50 or 75 ohms and a maximum V.S.W.R. of 1.2 at the highest rated frequency.

The impedance matching transformers have been designed to match, with minimum loss, 50 to 75 ohms, 50 to 93 ohms, and 75 to 95 ohms, over the frequency range of DC to 1000 mcs.

CHARACTERISTICS

	ATTENUATORS & TERMINATIONS						IMPEDANCE MATCHING TRANSFORMERS		
Model	HFA & HFT		HFA/T & HFT/T		HFA/N & HFT/N		HFAM		
Input/output impedance, ohms	50, 75	50, 75	50, 75	50, 75	50	50	50 75, 93	75 50, 93	93 50, 75
Nominal attenuation (db)	1, 2, 3, 4, 6, 10, 12, 15, 20 / 2, 3, 6, 10, 20		1, 2, 3, 4, 6, 10, 12, 15, 20 / 2, 3, 6, 10, 20		1, 2, 3, 4, 6, 10, 12, 15, 20		minimum loss		
Frequency range (mcs)	DC-1000		DC-2000		DC-2500		DC-1000		
Maximum V.S.W.R.	1.2 at 1000 mcs		1.2 at 2000 mcs		1.2 at 2500 mcs		1.2 at 1000 mcs		
Connectors	Type BNC		Type TNC		Type N		Type BNC		

For full information and prices write to

Applied Research inc.

76 SOUTH BAYLES AVENUE, PORT WASHINGTON, NEW YORK

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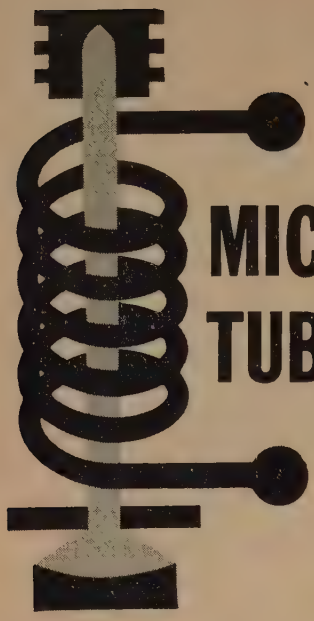

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The Electron Tube Division of Litton Industries has an international reputation for its capability in translating advanced concepts into microwave devices of high reliability. In part this is due to management by experienced engineers and, as a design engineer here, you will have well qualified support people on your team.

You will be working for a large company but...

You will be working in a small group on the product of your choice—TWT's, Superpowered Klystrons, crossed field amplifiers, or other sophisticated microwave devices.

Choose research or design and development, whichever field interests you most.

The location is in the San Francisco Bay Area. Your children will belong to one of the nation's great elementary school systems. You, yourself, will be close to all the cultural activities of San Francisco, the Berkeley campus of the University of California, Stanford University, San Jose State College, and the University of Santa Clara.

Openings exist for Senior, Project and Junior Engineers. Junior Engineers need have no experience beyond their baccalaureate in E.E. or Physics.

We assist with relocation expenses. Interviews may be arranged by writing, or telephoning collect to:

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960 Industrial Road
San Carlos, California
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LITTON INDUSTRIES
Electron Tube Division
San Carlos, California

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Wheeler Laboratories	

ACCURACY IN RF MEASUREMENT

BRUNO O. WEINSCHEL
PRESIDENT

WEINSCHEL ENGINEERING
Kensington • Maryland

Introduction

ommunications and microwave neers are not often greatly con- ed about measurement accuracy. eneral, they feel that it is a dull ect better left to the experts. The suring equipment they use is fur- ed with statements of accuracy h they sometimes refer to, and it ly on the rare occasion when two rently reliable measurements dif- sufficiently to be confusing that average engineer becomes aware e whole problem of standards, ac- cy and precision. The importance tandards in the microwave field me apparent with the growth of plexity and interactions of elec- ic equipment. Accuracy of speci- ions and performance is becoming easingly significant to the military hence to the suppliers of military ronics, some of whom are already ely aware of certain problems in area. The present discussion is erned with measurements of CW er and voltage in the range from megacycles to 12 kilomegacycles and with related measurements of impedance, attenuation and insertion loss.

The usual distinction is made between "precision" and "accuracy." *Precision* refers to the repeatability of a measurement. This involves sensitivity and stability. *Accuracy* refers to the absolute accuracy of a measurement when it is compared with accepted national or international standards. A stable and sensitive measurement system, i.e. a precise measurement system, can be calibrated in absolute terms against accepted standards, so that an absolute accuracy can be assigned to its measurements. But the fact that a measurement is repeatable does not assure its accuracy. Accuracy should be "traceable" to the National Bureau of Standards. A listing of the accuracies to which National Bureau of Standards will calibrate on a routine basis is furnished in Tables IA, IB and IC. Higher accuracies have been reported by National Bureau of Standards for isolated measurements made with special equipment, requiring high skill, tedious effort, and excellent technique. Such results are listed in Table II.

At first glance, the accuracy figures in Tables 1A, B and C seem quite good, and most engineers would be quite content if they could measure to these accuracies. However, these are National Bureau of Standards figures. By the time these standards are related to routine laboratory measurements or data on production items, they have been degraded by transfer to secondary laboratory standards and from these to the item under test. The error in the final product can be enormously greater than the figures in Tables 1A, B and C depending on the transfer techniques used. The development of good comparison techniques and better standards are closely related. An advance in the state of the art will surely manifest itself in both directions. Further, it is a general fact that such advances come not only from an understanding of the subject,

(*Continued on page 90*)

TABLE 1A
CALIBRATION SERVICES AVAILABLE BY THE ELECTRONIC CALIBRATION CENTER, NATIONAL BUREAU OF STANDARDS
VOLTAGE MEASUREMENT, CW, UNBALANCED SINEWAVE

	Frequency	Range	NBS Best Routine Accuracy	Reference
rate voltmeters	30 kc-100 mc	.2-500 V	2%	#16, Page 23
	100, 300, 400, 500, 700 mc	.2-100 V	3%	#10
rate voltage sources: Micropotentiometers and signal rators	30, 100, 300 400, 500, 700 mc	1 microvolt-.IV	3%	#10

Note: The services above 300 mc were not available as of August, 1959.

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(*Continued from page 89*)

but from the exercise of ingen and the use of clever new ideas. those who work in this field will tify, it is far from being dull.

In recognition of the interplay standards, comparison techniques transfer devices, the National Bur of Standards furnishes data on equ ment in two forms, a calibration a certificate. The former merely sents the result of their measurem and its accuracy. The latter imp some degree of permanence to property certified and will be nished only on equipment in wh stability there is a considerable deg of confidence.

II. Methods and Sources of Err

The accuracies shown in Tables B and C are strongly interrela Voltage measurements in this quency range, for example, are n made directly but are based on po and impedance measurements. At uation measurements depend on p er ratio and impedance measureme The measurement of impedance in axial transmission lines has had sufficient attention. An absolute m urement of a 50 ohm resistive im dance at 1,000 mc, using a type connector, to a 1% accuracy, requ exceptional equipment and good t niques. The associated connector p lem is treated in National Bureau Standards Research Paper 2480 coaxial r-f connectors (Ref. 1). long as a slotted line is very unif and precise, the residual VSWR to connectors can be corrected by plication of Feenberg's nodal s method (Ref. 2). This is a good ample of a significant improvemen standards and techniques due to i nuity. An example of a comme application of such corrections is Model K04-999B Null Shift se Hewlett-Packard, which may be to calibrate out the residual VS of the H.P. 805 slab line.

Power measurements are comm made with bolometer mounts bridge circuits. Many users cons only the bridge circuit and indic errors and do not realize the e inherent in the mount. A ce amount of power is absorbed bet the reference plane through the i connector and the terminals of bolometer due to small losses in

TABLE IB
CALIBRATION SERVICES AVAILABLE BY THE ELECTRONIC CALIBRATION CENTER, NATIONAL BUREAU OF STANDARDS
ATTENUATION MEASUREMENT

	Frequency	Range	NBS Best Routine Accuracy	Reference
ial 50 ohm impedance, 1 male, male "N" connector	30-300 mc 300-4000 mc	.1-70 db	.05 db + .1% of attenuation in db	#16, Page 22
Waveguide				
RG-48/U	2.6-3.95 kmc			
RG-49/U	3.95-5.85 kmc	0-40 db	fixed pads .2 db or 1% of attenuation; variable attenuators: .1 db or	#10
RG-50/U	5.85-8.20 kmc			
RG-51/U	7.05-10.00 kmc			
RG-52/U	8.20-12.40 kmc	0-70 db	1% of attenuation	

ing dielectrics, in metal surfaces porous plating. In a carefully gned coaxial mount, a typical loss ,000 mc is about .2 db or 5% in er (Ref. 3). In addition to this r, there exists a lack of equiva- e between the substituted low uency power and the r-f power rbed in the substitution element, to the difference in distribution he r-f and d.c. currents in the meter. The first error is known *mount efficiency"* error, while the nd is called *"substitution"* error. total effect of both errors is wn as *"effective efficiency."* Also, power reflected by the mount due ts VSWR must be corrected for. re we come again to the problem impedance measurement.) The t of all three errors is lumped ther in the *"calibration factor,"* ch is the ratio of d.c. substituted er to incident r-f power at the in- terminal.

calorimeter often is considered panacea of all ills in power meas- nents, since the measurement of perature rise is an old art. How- , it requires careful design to min- e heat losses, measure temperature representative point, use good ing technique in flow calorimeters and correct for the heat created by fluid friction (Ref. 4). For dry calorimeters, the time constant is generally long and excellent stability of source and instruments is required. One source of systematic error is the absorption of power in the "thermal isolator," that section of the transmission line between the input and the dissipating device. This loss can be measured and applied as a percentage correction. However, the loss must be measured with input and output impedances identical to those of the line and calorimeter. Thus we come once more to rely on impedance measurements. This is readily illustrated by the instruction book for the Hewlett-Packard calorimeter, Model 434A, where at 10,000 mc, a correction factor of 2% plus 2% minus 1% is furnished (Ref. 5).

The present limitation on the absolute accuracy of insertion loss measurements in coaxial lines, in contrast to measurements in waveguide, is again the uncertainty to which the receiving and sending impedances are known. While two different laboratories can each measure the same attenuator pad with a precision of .01 db, these measurements may differ by .05 db if the pad has a VSWR of 1.30 and if there exists an absolute inaccuracy of 5% in setting up the sending and receiving impedances to an indicated VSWR of 1.00. This influence of the "scattering matrix" can be better understood by referring to Beatty's paper on "mismatch errors," (Ref. 6).

In measuring voltage by the output of a signal generator, it is necessary to know the output impedance of the generator as well as the load impedance in the connecting plane of the transmission line, because, as noted, the measurement is based on power. An inaccuracy in either impedance of 10% will cause an error of 5% in the voltage. In order to be less dependent on load impedance, a standard source of r-f voltage should act as a "constant voltage source." This can be achieved if the output impedance is low relative to the load impedance or if the voltage in the connecting plane is held constant. This usually does not hold true when using a matched signal generator as a source of power.

There are no simple methods for checking the output calibrations of signal generators at low levels. Signal generator manufacturers rely mostly on the design of the output attenuator.

TABLE IC
CALIBRATION SERVICES AVAILABLE BY THE ELECTRONIC CALIBRATION CENTER, NATIONAL BUREAU OF STANDARDS
POWER MEASUREMENT, CW

	Frequency	Range	NBS Best Routine Accuracies	Reference
alanced 50 ohm, Type "N" ctor	1-100 mc 100-300 mc	1-10 mw 1-100 mw	1%	#16, Page 22
oration of absorption power r and feed-thru type (higher)	30, 100, 200, 300 mc 30 mc 100, 200 300 mc	.1 mw-12 w 12-200 w 12-100 w	½% to 5% depending upon level	#10
oration of bolometer mounts hm "N" connector	300-4000 mc	1-10 mw	1%	#10 Note: These services were not available as of August, 1959.
Waveguide RG-48/U	2.60-3.95 kmc	1-10 mw	1%	
Waveguide RG-52/U	8.20-12.40 kmc	1-10 mw	1%	#10

TABLE II

BEST OBTAINABLE ACCURACY AS PUBLISHED BY THE NATIONAL BUREAU OF STANDARDS

	Frequency	Range	NBS Best Published Accuracy	Reference
Thermistor bridge including mount		0-100 mw	½%	#11, Page 91
		.1 mw - 100 mw	5% to .05%	#14, Page 263
Bolometer bridge including mount	to 300 mc	1 mw - 10 w	½%	#11, Page 91
Dry static calorimeter		200 mw - 20 w	½%	#11, Page 91
		20 mw - 12 w	.5% + .2 mw	#14, Page 29
Determination of effective efficiency of X-band bolometer mount, waveguide	9,375 mc	---	.2%	#12 Note: The USA and United Kingdom standards in X-b agree within 1.3 (Ref. 13)
Liquid flow calorimeter	0-2500 mc	10-350 w	1%	#14, Page 26 not yet reduced t practice

This neglects the influence of signal leakage, which is often sufficient to make the dial readings practically meaningless below —90 dbm (Refs. 7 and 8).

III. Conclusion

Some of these accuracies, after degradation from primary standards to production measurements, are clearly inadequate to satisfy present needs. In many cases, the accuracies stated in commercial specifications or military orders are such that they can hardly be met with present techniques. As a corollary (fortunate in some respects), they are difficult to verify. However, the development of more accurate standards and measurements in microwaves seems to have been neglected in our overall planning. There has been no coordinated planning in industry or in the professional societies and very little at the government level to methodically advance the art of precision measurement. To the extent that spot planning has been done, the staffing of our government and military agencies is inadequate to cope even with that limited planning. The National Bureau of Standards stated, in August 1959, when describing its effort in the area of radio-frequency and microwave measurements: "This program has been maintained at a level that has not kept up with the extremely rapid advances in new types of radar, navigation, and communication systems . . ." (Ref. 9.)

The writer hopes that the requirement of the military Quality Control Services for traceability of accuracy claims to National Bureau of Standards, will eventually result either in a redesign of equipment to meet published specifications or in a change of specifications to more realistic figures. In our free economy, this "house cleaning" in the industry should proceed on a voluntary basis without need for government interference. This trend will accelerate as additional National Bureau of Standards facilities become available. Our professional societies such as the American Institute of Electrical Engineers and the Institute of Radio Engineers, in combination with National Bureau of Standards, American Standards Association and Electronic Industries Association, can render a great service in this field.

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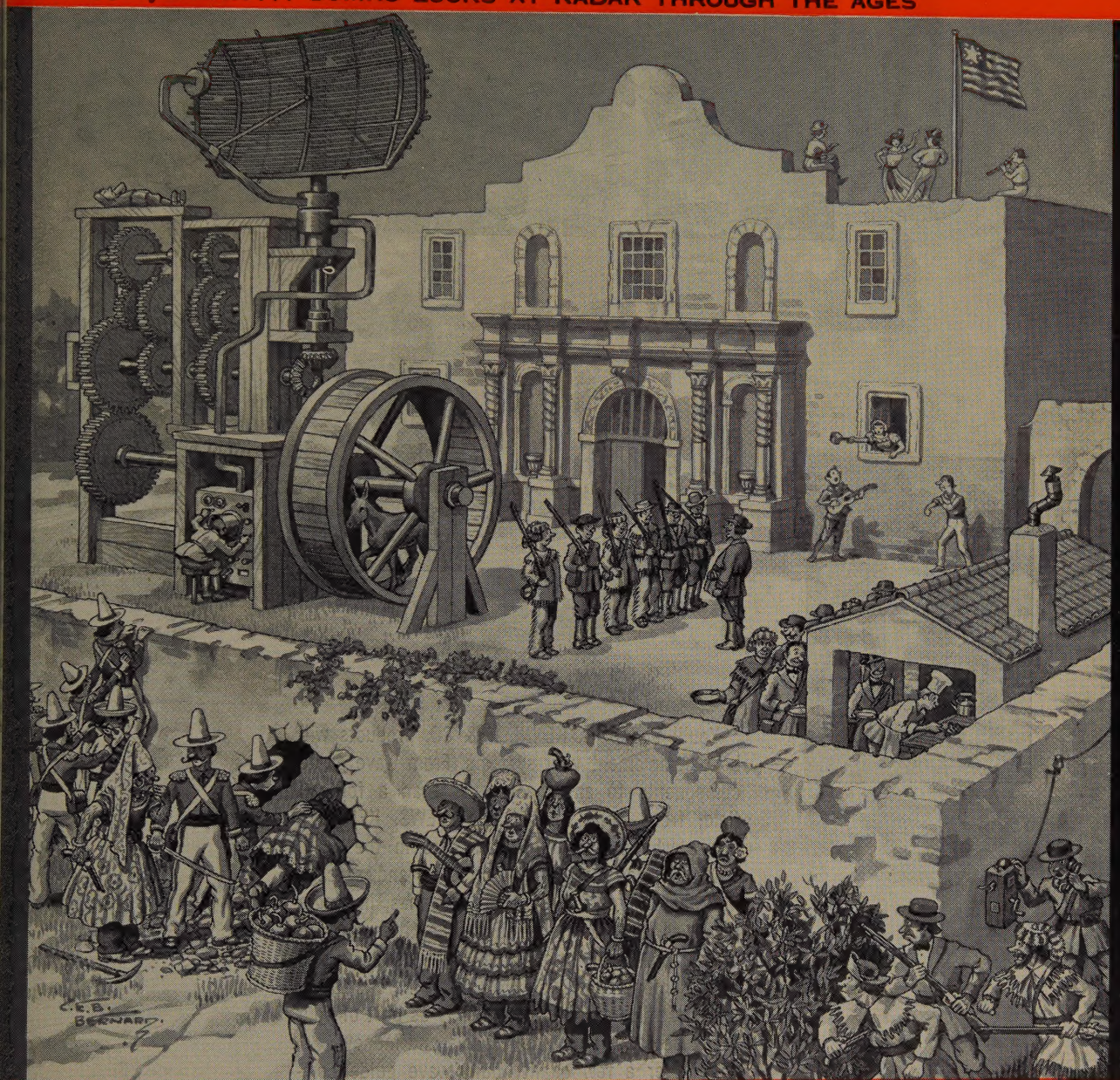

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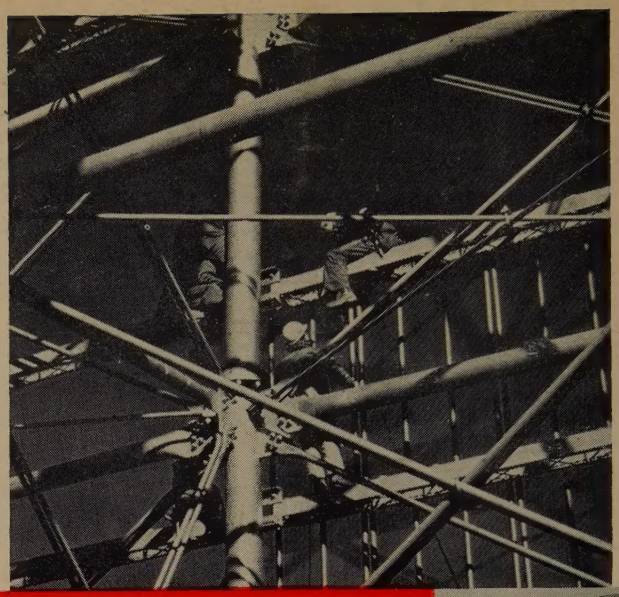

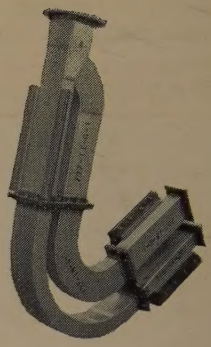

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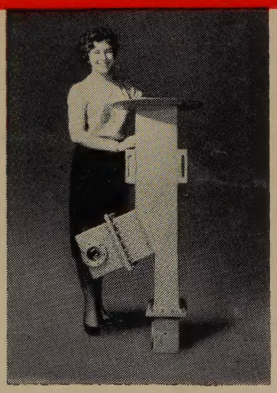

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